Joint Agency Staff Report on Assembly Bill 8: 2016 Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California

California Energy Commission

California Air Resources Board

Edmund G. Brown Jr., Governor

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ABSTRACT

The *Joint Agency Staff Report on Assembly Bill 8: 2016 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Fueling Stations in California* (2016 Joint Report) follows the first joint report published in 2015 in accordance with Assembly Bill 8 (AB 8) (Perea, Chapter 401, Statutes of 2013). The 2016 Joint Report updates the time and cost assessments to design, permit, construct, and make hydrogen refueling stations operational and open retail for the stations funded under the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP).

As of December 5, 2016, 25 open retail stations are selling hydrogen for use as a transportation fuel and another 23 stations are under development to become open retail and sell hydrogen to the public. Combined with two additional California Air Resources Board-funded stations that are open non-retail (not selling hydrogen to the public), California's hydrogen refueling station network is composed of 50 stations. This year has seen the greatest growth in the number of open retail stations in California since the AB 118 (Núñez, Chapter 750, Statutes of 2007) and AB 8 programs started. When the 2015 Joint Report was published, six stations were open retail.

ARFVTP funding remains necessary to reach the milestone of constructing and operating 100 hydrogen refueling stations. The 2016 Joint Report estimates the remaining cost to reach the 100-station milestone is about $125 million. Added to the investment reported in the 2015 Joint Report of over $100 million, which includes $80.9 million for infrastructure for 50 stations, the total cumulative cost is estimated at $225 million. With the business-as-usual $20 million per year in ARFVTP funding, the 100-station milestone is projected to be achieved in 2024.

Keywords: California Energy Commission, California Air Resources Board, Alternative and Renewable Fuel and Vehicle Technology Program, AB 8, hydrogen, hydrogen refueling station, fuel cell electric vehicle, National Renewable Energy Laboratory.

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ACRONYMS

AB	Assembly Bill
AHJ	Authority having jurisdiction
ARB	California Air Resources Board
ARFVTP	Alternative and Renewable Fuel and Vehicle Technology Program
BOE	California Board of Equalization
CAEATFA	California Alternative Energy and Advanced Transportation Financing Authority
CaFCP	California Fuel Cell Partnership
CAL FIRE	California Department of Forestry and Fire Protection
CDFA	California Department of Food and Agriculture
CHIT	California Hydrogen Infrastructure Tool
CI	Carbon intensity
CLEEN	California Lending for Energy and Environmental Needs
CTEP	California Type Evaluation Program
DMS	CDFA Division of Measurement Standards
DMV	California Department of Motor Vehicles
U.S. DOE	U.S. Department of Energy
FCEV	Fuel cell electric vehicle
GFO	Grant funding opportunity
GHG	Greenhouse gas
GO-Biz	Governor's Office of Business and Economic Development
H2FIRST	Hydrogen Fueling Infrastructure Research and Station Technology
H35	Hydrogen at a pressure of 35 mega Pascal, also called 350 bar
H70	Hydrogen at a pressure of 70 mega Pascal, also called 700 bar
HyStEP	Hydrogen Station Equipment Performance
IBank	California Infrastructure and Economic Development Bank
LCFS	Low Carbon Fuel Standard
MPO	Metropolitan Planning Organization
NFPA	National Fire Protection Association
NREL	National Renewable Energy Lab
O&M	Operations and maintenance
PHEV	Plug-in hybrid electric vehicle
PON	Program opportunity notice
POS	Point-of-sale
SAE	Society of Automotive Engineers
SB	Senate Bill
SCAQMD	South Coast Air Quality Management District
SMR	Steam methane reformation
SNL	Sandia National Laboratories
STE	Sales and use tax exclusion
TFCA	Transportation Fund for Clean Air
ZEV	Zero-emission vehicle

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Page

EXECUTIVE SUMMARY

This report describes the progress the State of California has made in supporting hydrogen fuel cell electric vehicles (FCEVs) and hydrogen refueling stations. These activities align with and support Governor Brown's vision to encourage and increase the adoption of zero-emission vehicles (ZEVs) to reach 1.5 million ZEVs by 2025. The California Energy Commission (Energy Commission) and the California Air Resources Board (ARB) should stay the course on hydrogen FCEVs and hydrogen refueling stations.

Assembly Bill 8 (AB 8) (Perea, Chapter 401, Statutes of 2013) directs the Energy Commission to annually allocate up to $20 million from the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP) for the development of hydrogen refueling stations until at least 100 stations operate publicly. Hydrogen FCEVs, a type of ZEV, require hydrogen refueling stations the same way that traditional gasoline-fueled vehicles require gas stations. FCEVs have similar ranges as traditional vehicles and have a similar refueling process—it takes a matter of minutes to refill the fuel tank from a station dispenser.

Because ZEV commercialization and adoption are two of California's strategies for reducing greenhouse gas (GHG) emissions and criteria pollutants from the transportation sector, AB 8 allocated specific funding to support FCEV deployment in California by investing in the refueling infrastructure necessary to support the early FCEV market.

AB 8 established two reporting requirements:

(1) ARB is to annually evaluate, by June 30, the need for additional hydrogen refueling stations by geographic area, based on the number of FCEVs projected to be sold or leased from auto manufacturers, and the number of FCEVs currently registered in the state. ARB's *2016 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development* (2016 Annual Evaluation) also recommends technical and operating specifications for future stations.

(2) The Energy Commission and ARB are to work together to jointly report, by December 31 of each year, the remaining cost and timing to establish the network of 100 hydrogen refueling stations. The *Joint Agency Staff Report on Assembly Bill 8: 2016 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California* (2016 Joint Report) addresses this requirement.

The contents of the joint report are further prescribed by AB 8, as follows:

- Report on the coverage and capacity of the hydrogen refueling station network being developed.
- Consider the rate at which FCEVs are being deployed by auto manufacturers, and the corresponding amount of fuel needed to support that demand.
- Evaluate the length of time required to permit and construct stations.

- Determine if ARFVTP funding remains necessary to achieve the 100 station goal.

The Energy Commission tracks the progress of station development from the beginning of the grant funding agreement to when a station becomes “open retail.” This year, 2016, has seen the greatest growth in the number of open retail stations in California since the AB 118 (Núñez, Chapter 750, Statutes of 2007) and AB 8 programs started. As of the publication of this Joint Report, there are 25 open retail stations in California, an increase in 19 stations from the 6 that were open retail when the last joint report was published in December 2015.

Table ES-1 shows the quarterly progress of operational and open retail stations. An operational station meets technical standards for fueling protocols and hydrogen purity, among other technical requirements. An open retail station is tested according to State of California norms and can sell the hydrogen as a transportation fuel at retail.

Table ES-1: Progress of Stations Reaching Operational and Open Retail Status

Quarter / Year	Operational	Open Retail
4 / 2015	7	6
1 / 2016	4	14
2 / 2016	3	20
3 / 2016	5	21
4 / 2016*	1	25

* Q4 is through December 6, 2016.

Source: California Energy Commission staff

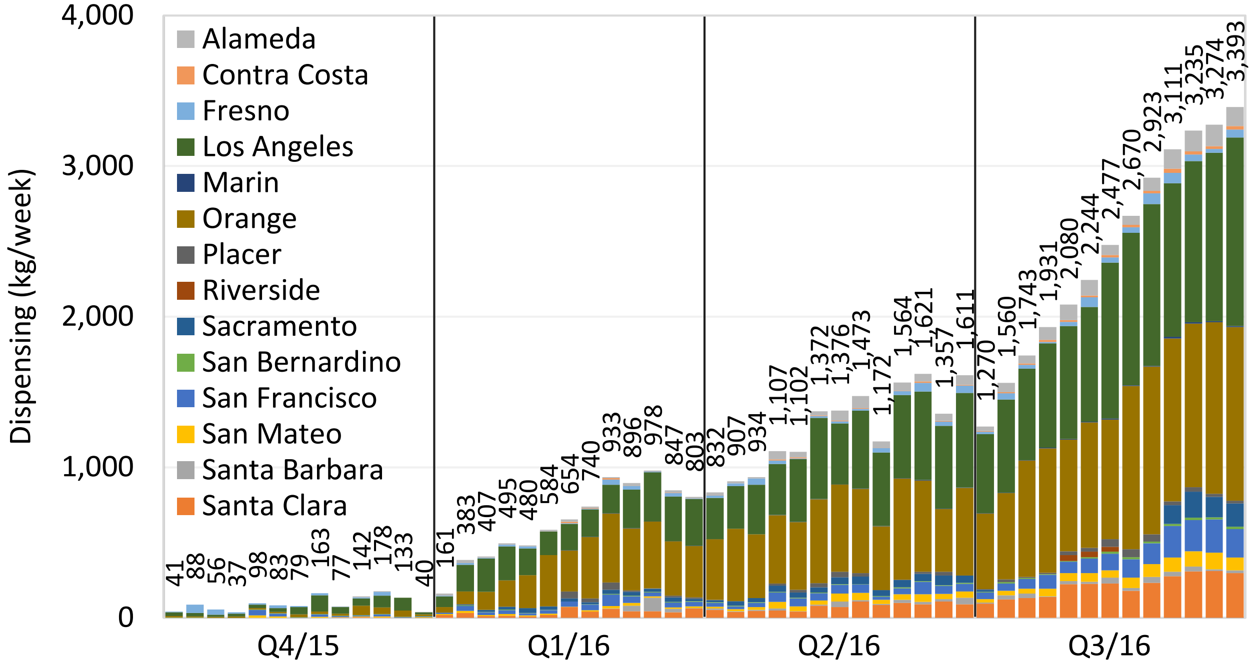
Beyond the 25 open retail stations, an additional 23 stations are funded and under development, for 48 ARFVTP-funded stations. At the time of last year’s joint report, there were 49 ARFVTP-funded stations, but the Energy Commission has since pulled funding for one station upgrade. The ARFVTP has also funded a temporary refueler that is not included in these numbers.

Combining the 48 ARFVTP-funded stations with 2 ARB-funded stations in Harbor City and at California State University, Los Angeles (CSULA), which are presently open and non-retail (a non-retail station is one that may sell hydrogen to the public, but requires individual auto manufacturer approval for use by drivers of its FCEVs), California’s hydrogen refueling station network consists of 50 stations.

This year has also seen encouraging growth in FCEV rollout. There are 925 FCEVs registered with the California Department of Motor Vehicles (DMV) as of October 5, 2016. This is an increase from the 331 FCEVs registered as of April 2016 and nearly 200 registered as of October 2015. Even with this growth, ARB’s updated projections of FCEV deployment show a lag in expected deployment in the short term, but later-year deployment, in 2020-2022, exceeds what has been previously reported. ARB’s most recent projections are for 13,500 FCEVs to be on California roads by 2019 and 43,600 by 2022.

This Joint Report analyzes and presents hydrogen refueling station data from the fourth quarter of 2015 and the first three quarters of 2016. Appendix D includes information about the quarterly statistics of the hydrogen refueling station network utilization in California. Figure ES-1 shows the amount of hydrogen dispensed per week from the fourth quarter of 2015 through the third quarter of 2016. The growth in FCEV deployment is reflected in Figure ES-1, which reveals a striking increase in the amount of hydrogen being dispensed statewide.

Figure ES-1: Weekly Hydrogen Dispensing by County



Source: NREL

The growth of the hydrogen refueling station network is integral to providing potential customers with confidence about driving a FCEV. To succeed in creating a network that provides this confidence, station network growth needs to occur such that FCEV demand for hydrogen fuel is met. Today's open retail stations provide a hydrogen supply that exceeds the demand of the FCEVs registered in California. ARB's 2016 Annual Evaluation compares projected FCEV rollout with projected hydrogen refueling station network growth, assuming existing investment levels and with typical station capacity remaining the same ("business-as-usual"). Under these assumptions, the projections indicate that California will have a hydrogen dispensing capacity shortfall around 2020. To avoid this shortfall, the Energy Commission, ARB, and their partners are working to ensure future stations provide effective statewide coverage and appropriate capacity, and are working to reduce the time and cost of station development.

Hydrogen refueling station development time has decreased from, on average, over four years for the 7 open retail stations of the 10 funded in Program Opportunity Notice (PON)-09-608, to two years for the 16 open retail stations of the 28 funded in PON-13-607. The station that progressed from permitting and construction to open retail the quickest is the station in Coalinga. It reached open retail status in roughly 17 months. The Energy Commission encourages timely station development by enforcing “Critical Milestones” in its most recent Grant Funding Opportunity (GFO)-15-605. Grant recipients will be required to have in-person preapplication meetings with the appropriate authority having jurisdiction (AHJ) over the station location and to have control and possession of the station site before the Energy Commission will pay any money to the recipient. This action is intended to help expedite hydrogen refueling station development.

As of September 30, 2016, the average equipment, design, engineering, construction, project management, and overhead costs have been about $2.4 million for stations designed for supply by delivered gaseous hydrogen and $2.8 million for designs based on delivered liquid hydrogen. The on-site electrolysis station in this report anticipates $3.2 million for these costs. These are all-in costs, which include ARFVTP equipment costs, match funding, and other costs paid by the station developer. The average annual operations and maintenance (O&M) grant has been $100,000 per year for all types of systems, with stations eligible for up to three years of O&M support.

The 2016 Joint Report estimates the remaining cost to reach the 100-station milestone is nearly $125 million. Added to the investment reported in the 2015 Joint Report of over $100 million, which includes $80.9 million for infrastructure, the total cumulative cost is estimated at $225 million. With the business-as-usual $20 million per year in ARFVTP funding, the 100-station milestone is projected to be achieved in 2024.

The Energy Commission and ARB are establishing a framework to evaluate the potential for various entities to achieve financial self-sufficiency in hydrogen infrastructure ventures and to answer the questions: “When will California’s hydrogen refueling stations become self-sufficient?” and “When will the stations support their operating costs?” Perspectives of gas station owners, industrial gas companies, independent operators, early vehicle drivers, and others will be reviewed and synthesized.

The Energy Commission and ARB will continue to work together on joint analyses and technical activities related to expeditious station development to attain the 100-hydrogen refueling station goal. Future Joint Reports will include information about these efforts and the results that follow.

CHAPTER 1: Introduction

This 2016 Joint Report reviews and reports on the progress of fuel cell electric vehicle (FCEV) use and of hydrogen refueling station rollout. Based on these findings, this Joint Report estimates the additional amount of time and funding required to attain 100 hydrogen refueling stations. This Joint Report is based on actual expenditures and projections. The following quarters are reported: the fourth quarter of 2015 and the first three quarters of 2016.

Background

Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) directs the Energy Commission to allocate up to $20 million annually, not to exceed 20 percent of the amount of funds appropriated by the State Legislature from the Alternative and Renewable Fuel and Vehicle Technology Fund, for developing hydrogen refueling stations "until there are at least 100 publicly available hydrogen-fueling stations in operation in California" (Health and Safety Code 43018.9[e][1]). AB 8 reauthorized the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP) created by Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) from January 1, 2016, to January 1, 2024.

AB 118 names the Energy Commission as the ARFVTP administrator, tasked with providing various financial incentives to develop and deploy innovative technologies to transform the transportation sector and help attain climate change goals defined in Assembly Bill 32 (Núñez and Pavley, Chapter 488, Statutes of 2006) and now Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016). A FCEV is one type of zero-emission vehicle (ZEV), along with other types of electric vehicles, identified in the *State Implementation Plan*[1] and the *Climate Change Scoping Plan*[2] to help California reduce air pollution and greenhouse gas (GHG) emissions.

AB 8 also directs ARB and the Energy Commission to carry out specific tasks. ARB is to collect and report annually the number of FCEVs that vehicle manufacturers project to be sold or leased over the next three years and the total number of FCEVs registered in the state by June 30. Based on these numbers, ARB is to evaluate and report the need for additional publicly available hydrogen refueling stations over the next three years, including "the number of stations, geographic areas where additional stations will be needed, and minimum operating standards, such as number of dispensers, filling protocols, and pressures." (Health and Safety Code 43018.9[d][2]). ARB's *2016 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development* (2016 Annual Evaluation) satisfies these requirements. The annual evaluation contains results from an annual survey of auto

1 California Air Resources Board. *Mobile Source Strategy*. May 2016. p. 66. https://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf.

2 California Air Resources Board. *First Update to the Climate Change Scoping Plan*, Transportation Appendix. May 2014. https://www.arb.ca.gov/cc/scopingplan/2013_update/transportation.pdf.

manufacturers' deployment plans for FCEVs in California and identifies where new infrastructure is most needed to support FCEV use and refueling.

With the information from ARB's annual evaluation, AB 8 requires that, by December 31 of each year, the Energy Commission and ARB work *together* to:

> Review and report on progress toward establishing a hydrogen-fueling network that provides the coverage and capacity to fuel vehicles requiring hydrogen fuel that are being placed into operation in the state. The commission and the state board shall consider the following, including, but not limited to, the available plans of automobile manufacturers to deploy hydrogen-fueled vehicles in California and their progress toward achieving those plans, the rate of deployment of hydrogen-fueled vehicles, the length of time required to permit and construct hydrogen-fueling stations, the coverage and capacity of the existing hydrogen-fueling station network, and the amount and timing of growth in the fueling network to ensure fuel is available to these vehicles. The review shall also determine the remaining cost and timing to establish a network of 100 publicly available hydrogen-fueling stations and whether funding from the Alternative and Renewable Fuel and Vehicle Technology Program remains necessary to achieve this goal. (Health and Safety Code 43018.9[e][6])

This *Joint Agency Staff Report on Assembly Bill 8: 2016 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California* (2016 Joint Report) from the Energy Commission and ARB satisfies these requirements.

Organization of This Joint Report

The 2016 Joint Report is organized to address the various considerations named above, in the following chapters:

- Chapter 1: Introduction
- Chapter 2: Coverage and Capacity of the Hydrogen Refueling Station Network
- Chapter 3: Fuel Cell Electric Vehicle Deployment
- Chapter 4: Length of Time Required to Permit and Construct Hydrogen Refueling Stations
- Chapter 5: Amount of Growth and the Timing of Growth of the Refueling Network
- Chapter 6: Remaining Cost and Timing to Establish a Network of 100 Publicly Available Hydrogen Refueling Stations
- Chapter 7: Conclusions

Chapter 2, on coverage and capacity, provides station location maps that include the amount of hydrogen that can be dispensed daily, and a coverage map that shows coverage provided by the open and funded hydrogen refueling station network. Appendices contain details about the location and status of each station, hydrogen dispensing trends, and station throughput.

Chapter 3 reports the FCEV deployment. Detailed information about how the deployment compares with past projections is found in ARB's 2016 Annual Evaluation.[3]

Chapter 4 explains the phases of station development and summarizes the progress. This section describes some of the strategies employed by the Energy Commission, ARB, and the Governor's Office on Business and Economic Development (GO-Biz) to encourage faster progression through the station development phases so that California's hydrogen refueling stations reach open retail status and sell hydrogen. Additional information on the station planning process and applicable codes and standards is in the appendices.

Chapter 5, describing the growth of the refueling network, includes projections for both station and FCEV deployment and evaluates these two activities together to analyze if the supply of hydrogen offered by stations will meet the demand for hydrogen from FCEVs in operation.

Chapter 6, on the cost and timing of reaching the 100-station milestone for the hydrogen refueling station network, delves into the amount of money needed to design, construct, and operate stations. These findings are based on the actual numbers from operational and open retail stations.

Chapter 7 lists the conclusions of this joint report and explains that ARFVTP funding remains necessary to meet the 100-station milestone.

The appendices follow:

Appendix A explains a "self-sufficiency framework" that the Energy Commission and ARB are developing to determine when public funding for stations should no longer be necessary.

Appendix B explains station status terminology and station commissioning.

Appendix C discusses social and environmental impacts of hydrogen refueling stations.

Appendix D provides figures that visualize station use, over time and by time of day and day of week.

Appendix E discusses planning considerations and the codes and standards related to hydrogen refueling station development.

Appendix F contains additional details about capital expense costs and operation and maintenance (O&M) costs and provides information about other financial incentive programs that station developers may take advantage of, beyond ARFVTP funding.

Appendix G discusses other financial incentives for hydrogen station development.

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3 California Air Resources Board. 2016. *2016 Annual Evaluation of Hydrogen Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development.* pp.21-29. https://www.arb.ca.gov/msprog/zevprog/ab8/ab8_report_2016.pdf.

Appendix H provides a full list of the existing hydrogen refueling station network.

Appendix I provides references.

CHAPTER 2: Coverage and Capacity of the Hydrogen Refueling Station Network

Ensuring the coverage and capacity of the state-funded hydrogen refueling station network efficiently and effectively meets the anticipated demand from FCEV consumers is an important goal of the ARFVTP. The ARB 2016 Annual Evaluation details ARB's analytical and modeling activities that support the state's effort to encourage the appropriate location and size of stations. ARB's activities have included developing the California Hydrogen Infrastructure Tool (CHIT), which is discussed relative to the assessment of coverage and use in the latest hydrogen refueling station grant solicitation, GFO-15-605, later in this chapter.

California's hydrogen refueling station network consists of 50 stations. Of these, 48 are ARFVTP-funded, of which 25 have reached open retail status as of December 5, 2016. At the time of last year's joint report, there were 49 ARFVTP-funded stations, but the Energy Commission has since pulled back funding for one station upgrade. The network also includes the two ARB-funded stations in Harbor City and California State University, Los Angeles (CSULA), which are open non-retail (that is, selling hydrogen only to drivers of FCEV models with approval from the auto manufacturer). The ARFVTP has also funded a temporary refueler that is not included in these numbers.

Significant progress – more than in any previous year – has been made in opening new stations in 2016. When the 2015 Joint Report was published in December 2015, there were six open retail stations. These six stations are:

- In Northern California: West Sacramento.
- In Southern California: Diamond Bar, Los Angeles (West L.A.), Irvine (UCI), and San Juan Capistrano.
- Connector station in the Central Valley: Coalinga.

Through December 5, 2016, another 19 stations have reached open retail status:

- In Northern California: Hayward, Mill Valley, Truckee, South San Francisco, Campbell, San Jose, and Saratoga.
- In Southern California: La Cañada Flintridge, Long Beach, Los Angeles (Fairfax), Los Angeles (Playa Del Rey), Santa Monica, Costa Mesa, Lake Forest, Santa Barbara, Woodland Hills, Los Angeles (Hollywood), Anaheim, and Del Mar.

Table 1 shows the quarterly progression of both operational and open retail stations. For a full discussion of station status definitions, please see Appendix B.

- An **operational** hydrogen refueling station meets technical standards for fueling protocols and hydrogen purity, among other technical requirements.
- An **open retail** hydrogen refueling station is tested according to State of California norms and can sell the hydrogen as a transportation fuel at retail.

Table 1: Progress of Stations Reaching Operational and Open Retail Status

Quarter / Year	Operational	Open Retail
4 / 2015	7	6
1 / 2016	4	14
2 / 2016	3	20
3 / 2016	5	21
4 / 2016	1	25

Source: California Energy Commission staff

Station Locations

The station locations as of December 5, 2016, are shown in Figure 1. As of that date, there are 25 open retail hydrogen refueling stations, 23 stations in development, and two ARB-funded open, non-retail stations. These stations are mostly concentrated in early market communities in the Greater Los Angeles Area and the San Francisco Bay Area.

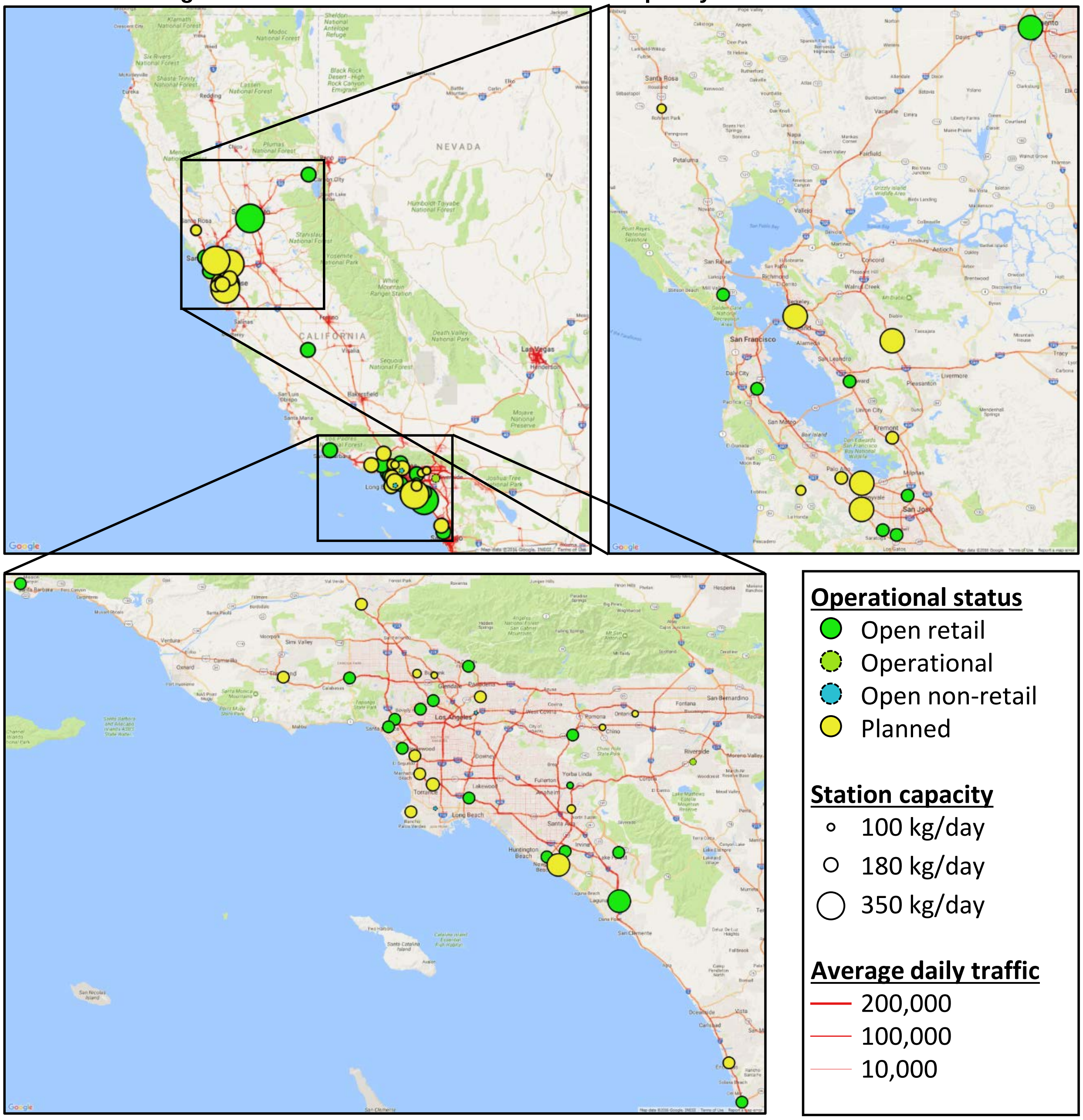
Most stations will be successful if they are placed in communities with a high likelihood of adopting FCEVs given ample convenient fueling opportunities, which in turn provides the station with certainty of utilization and revenue. Thus, the majority of stations are likely to be most successful when serving a high market potential area. However, a well-functioning fueling network has additional needs, such as fueling at connections between distant early market areas and fueling in popular vacation destinations.

To this end, an open retail station in Coalinga (located in Fresno County in the Central Valley) enables travel between Northern California and Southern California. One can now drive from San Diego to Los Angeles to Sacramento. The vacation destination of Lake Tahoe is covered by an open retail station in Truckee. Santa Barbara, which can be considered a destination, a connector, and a potential market area of its own, is also covered.

Figures 1, 2, and 3, besides offering a picture of the locations of the existing stations, also provide information about system capacity. The size of the station icon indicates the daily capacity of the station. Major roads are also shown according to the amount of average daily traffic.

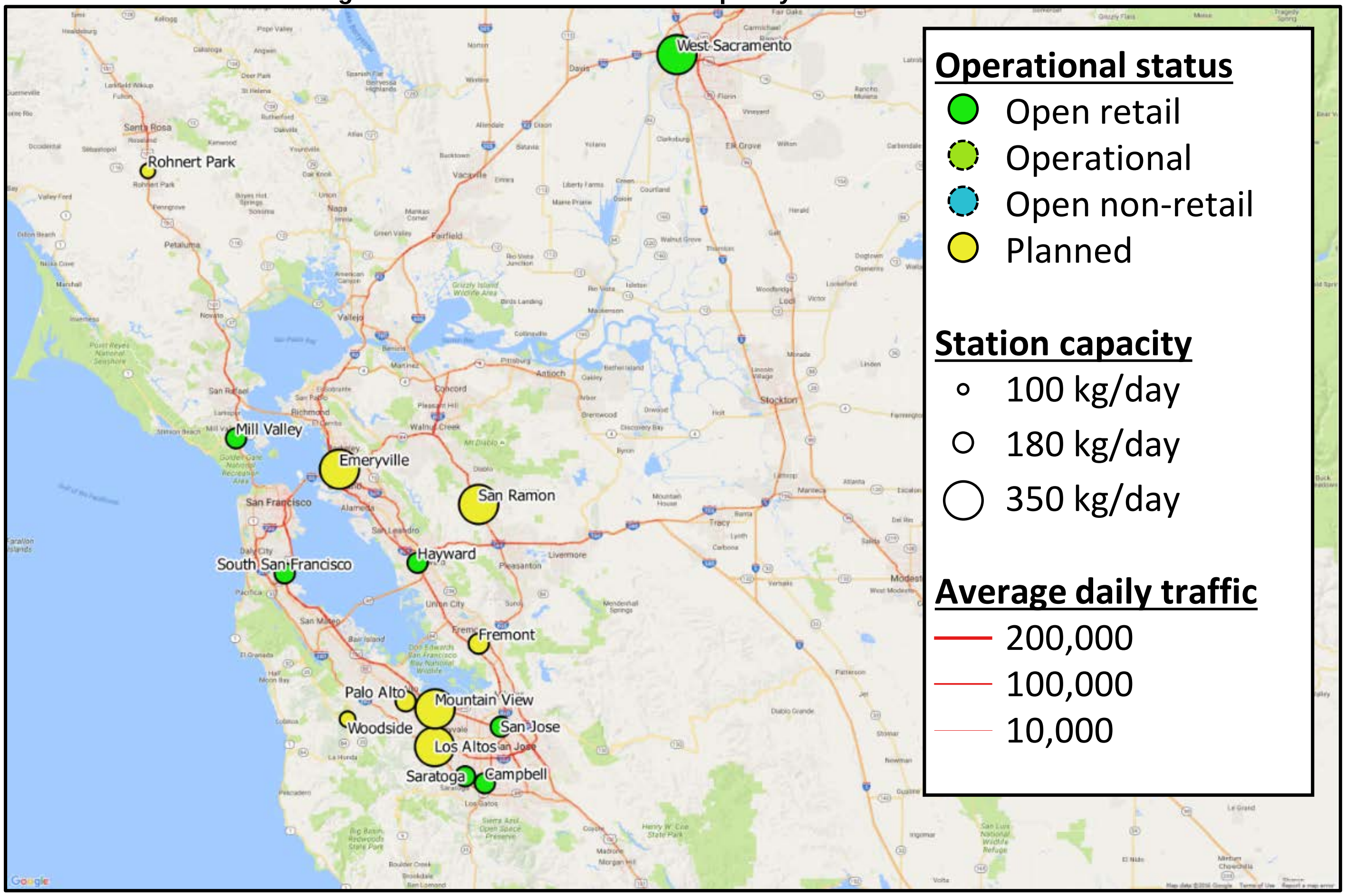
Appendix H lists the exact station addresses, along with the associated operational dates and open retail dates, as applicable.

Figure 1: Statewide Station Location and Capacity of Funded Stations



Source: National Renewable Energy Laboratory (NREL)

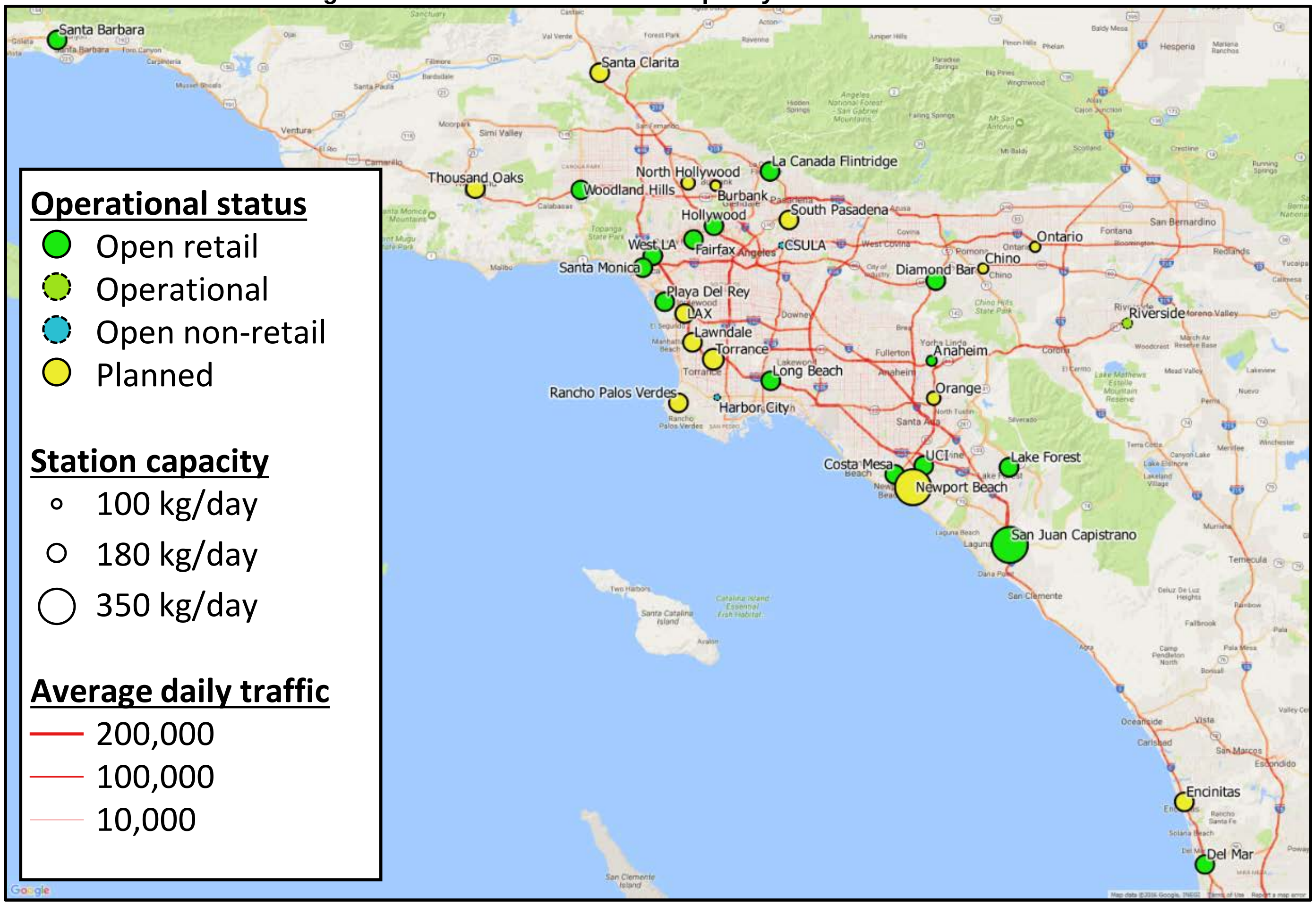
Figure 2: Station Location and Capacity Northern California



Source: NREL

Figure 2 shows the station locations for seven of the eight open retail stations in Northern California. The Truckee station near Lake Tahoe cannot be seen in this map view. An additional eight stations are currently under development (falling into the "planned" category). The capacity and annual average daily traffic flows are also shown as in the previous figure.

Figure 3: Station Location and Capacity Southern California



Source: NREL

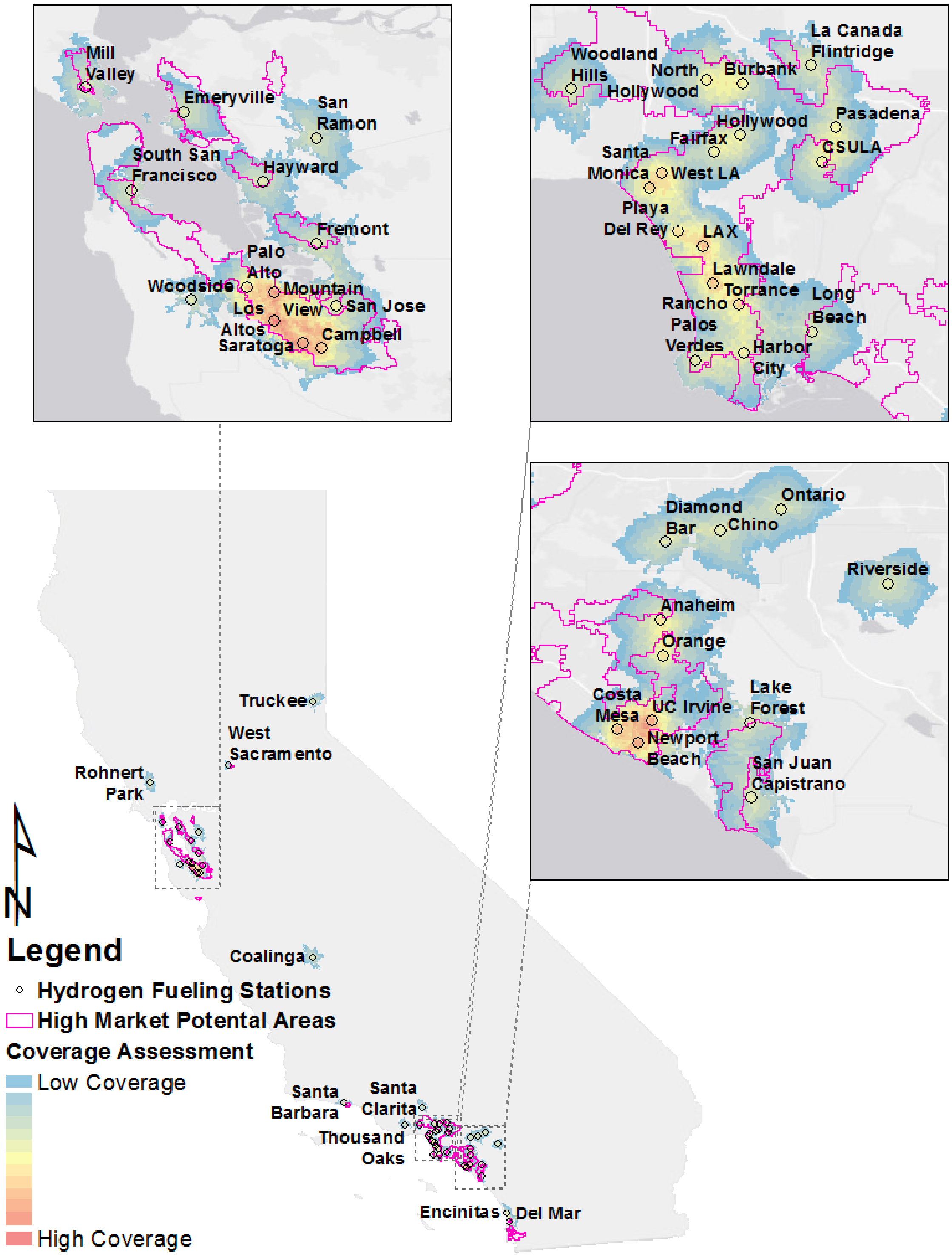
Figure 3 shows the station locations of the 16 open retail stations in Southern California and the one operational station (as of December 5, 2016). An additional 14 stations on the map are in the “planned” category. The two open, non-retail ARB-funded stations, Harbor City and CSULA, are also displayed. The capacity and annual average daily traffic flows are shown as in the previous figures. The open retail station in Coalinga in the Central Valley is represented only in Figure 1, the statewide map.

Evaluation of Coverage Provided to FCEV Early Adopter Market

As will be discussed further below, some station locations have changed since the release of the 2015 Joint Report. Changes in location for funded stations result in corresponding changes to the geographical distribution of coverage provided by the open and funded hydrogen refueling station network. Figure 4 provides an update to Figure 6 from the 2015 Joint Report, with new analyses based on the current station locations shown in figures 1 through 3. Magenta outlines in Figure 4 indicate the areas of highest market potential for early adoption of FCEVs.

The color shading in Figure 4 indicates the degree of local fueling coverage provided by the funded station network; red is the highest degree of coverage, yellow is an intermediate degree of coverage, blue is a minimal degree of coverage, and areas without color shading have no coverage at all. The degree of coverage was assessed through CHIT as first presented in the 2015 Annual Evaluation and described again in the 2016 Annual Evaluation. Coverage assessments in CHIT account for overlapping coverage provided by multiple stations and the drive time between neighborhoods and stations. The high market potential areas are similarly defined by a CHIT evaluation, based on several demographic indicators as first described in the 2015 Annual Evaluation.

Figure 4: CHIT Assessment of Coverage of High Market Potential Areas



Source: ARB

The changes in station locations since the 2015 Joint Report have altered the match between coverage and high potential market areas in several ways, as can be observed by comparing Figure 4 above to Figure 6 in the 2015 Joint Report:

- The anticipated upgrade of the Emeryville station to an open retail type of station has resulted in the first coverage to be provided to the high market potential area on the northeast side of the San Francisco Bay Area, which includes Berkeley and Oakland.
- Stations that have moved away from the western side of the San Francisco Bay Area have reduced the coverage on the peninsula between San Francisco and San Jose. In the 2015 Joint Report's evaluation, it was found that continuous coverage (of varying degrees) between South San Francisco and Campbell was provided by the then-funded network. With today's network, there is a gap between the coverage provided by the South San Francisco station and the next-closest stations on the peninsula, Woodside and Palo Alto.
- The high market potential area near Fremont has gained its first degree of coverage. In contrast to the above observation about the western side of the San Francisco Bay Area, the coverage near Fremont combined with the anticipated Emeryville upgrade has resulted in nearly full continuous coverage along the eastern side of the San Francisco Bay Area. Only a small gap exists near San Leandro and Castro Valley on the east side of the Bay.
- Coverage has been lost around Pacific Palisades. However, it is important to note that this is not a high market potential area. On the other hand, the new station location in North Hollywood has extended and strengthened the coverage provided in the high market potential neighborhoods in the Greater Los Angeles Area.
- The relocation of the Redondo Beach station to Rancho Palos Verdes near the South Bay has redistributed the intensity of coverage in the area. Notably, the area around Lawndale and Torrance has less overlapping coverage (and therefore a lesser degree of coverage), while coverage has been extended further into Rancho Palos Verdes and nearby communities.
- The intensity of coverage in the northern Irvine/Tustin area and near the southern Orange County cities extending between San Juan Capistrano and Lake Forest has decreased, due to a lesser degree of overlapping coverage provided by the current station network.
- New coverage has been added in Encinitas and Santa Clarita. While these are outside of the high market potential areas, these stations will likely serve important roles of redundancy as connector stations for mid- to long-range travel in the state.
- Though not a change from the 2015 Joint Report, it is also important to note that a high market potential area near Santa Cruz remains without any coverage. Also, the high market potential area surrounding San Diego has coverage only in the northernmost communities.

Station Network Daily Fueling Capacity

The network is comprised of stations with varying daily fueling capacities, reflected in figures 1, 2, and 3 by the icon size in the figures. The most common hydrogen refueling station capacity is 180 kg/day. Most FCEV fuel tanks hold approximately 5 kg of hydrogen. An Energy Commission staff assessment finds that the current average fill is around 3 kg. Assuming fills ranging from 3 to 5 kg, the 180 kg/day stations can provide a complete fill for 35 – 60 vehicles daily. A typical FCEV uses 0.7 kg/day of fuel,[4] meaning a station of this size can support a community of nearly 250 FCEVs.

The 48 ARFVTP-funded stations in the network have a fueling capacity of approximately 9,260 kg/day. Adding the two ARB-funded, open and non-retail stations in Harbor City and at CSULA, the 50 station hydrogen refueling network (existing and planned stations) has a daily fueling capacity of about 9,380 kg/day, enough fuel for more than 13,000 FCEVs.[5] Taking the network as a whole, this capacity is more than sufficient to fuel the existing FCEVs registered in California, and it is consistent with the Governor's *2016 ZEV Action Plan* recommendation to match demand and plan for capacity, distribution, and siting of hydrogen stations to support the initial deployment of vehicles.[6]

2016 Competitive Solicitation for Hydrogen Refueling Stations

Released by the California Energy Commission in April 2016, GFO-15-605, *Hydrogen Refueling Stations for Light Duty Vehicles*[7] offers up to $33 million for new station development, station upgrades, and operation and maintenance (O&M) of the stations. GFO-15-605 includes coverage, capacity, and market viability Evaluation Criteria to encourage prospective developers to choose sites for stations that best meet projected demand.

The modeling tool used for evaluating station coverage and capacity is CHIT, developed by ARB in 2015. CHIT assesses the station locations to be funded under GFO-15-605 by analyzing the need for fueling capacity at any particular site submitted by the grant applicants.[8]

To do this analysis, CHIT incorporates the existing station locations and capacities, DMV-reported FCEV registrations, the plans of automobile manufacturers to deploy hydrogen-fueled

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4 Pratt, Joseph, Danny Terlip, Chris Ainscough, Jennifer Kurtz, and Amgad Elgowainy. *H2FIRST Reference Station Design Task, Project Deliverable 2-2*. National Renewable Energy Laboratory and Sandia National Laboratories, 2015. p. 8. http://www.osti.gov/scitech/servlets/purl/1215215.

5 The 2015 Joint Report analyzed 51 stations with a total daily fueling capacity of 9,500 kg/day. Since, one station upgrade was withdrawn, and the total network fueling capacity decreased to 9,380 kg/day.

6 Governor's Interagency Working Group on Zero-emission Vehicles. *2016 ZEV Action Plan: A roadmap toward 1.5 million zero-emission vehicles on California roadways by 2025*. September 2016. p. 5. https://www.gov.ca.gov/docs/2016_ZEV_Action_Plan.pdf.

7 GFO-15-605 on Energy Commission website: http://www.energy.ca.gov/contracts/transportation.html#GFO-15-605.

8 California Air Resources Board. *2016 Annual Evaluation of Hydrogen Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development*. July 2016. https://www.arb.ca.gov/msprog/zevprog/ab8/ab8_report_2016.pdf.

vehicles in California, and the CHIT geographic assessment of demographic indicators for the localized strength of the FCEV first adopter market.

The Energy Commission considers additional criteria under GFO-15-605 to evaluate applications: team qualifications, safety planning, project readiness, station operation and maintenance, budget, financial plan, station performance, economic and social benefits, innovation, renewable hydrogen content (including from direct sources), sustainability and environmental impacts. As of the publication date of this 2016 Joint Report, the issuance of the GFO-15-605 Notice of Proposed Awards (NOPA) remains pending.

Figure 5: Anaheim Station Dispenser

Source: Air Liquide

One of the stations that became open retail in 2016 is in Anaheim. This report includes several photos from different stations in the California hydrogen refueling station network.

CHAPTER 3: Fuel Cell Electric Vehicle Deployment

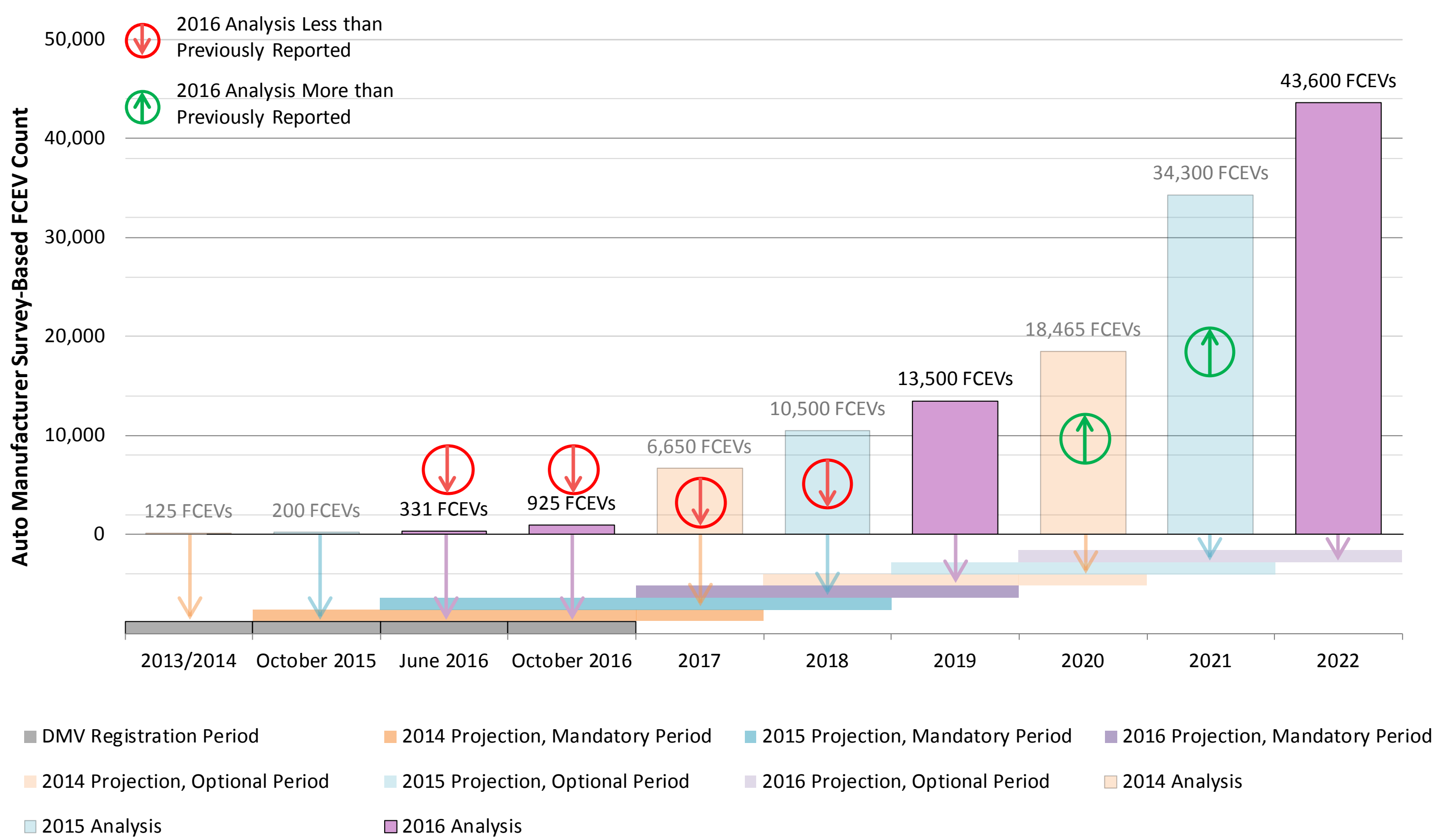
Figure ES3 in ARB's 2016 Annual Evaluation showed 331 FCEVs registered with the California Department of Motor Vehicles (DMV) as of April 2016. Figure 6 below is an updated version of ARB's Figure ES3, showing the latest DMV registration data as of October 5, 2016, which is 925 FCEVs. This is encouraging growth in FCEV deployment over the past six months.

Although the short-term FCEV deployment rate is slower than predicted, the market is expected to grow from the hundreds of FCEVs to the thousands in 2017. Figure 6 also shows ARB's latest survey results projecting 13,500 FCEVs in 2019 and 43,600 in 2022. ARB's latest survey also suggests there will be more FCEVs in California than previously projected by 2020, indicating that regardless of the short-term delay, strong growth is anticipated later. As stated in ARB's 2016 Annual Evaluation, the vehicle delay matches the station delay.[9] The Energy Commission's *Tracking Progress: Zero-Emission Vehicles and Infrastructure*[10] cites ARB's FCEV deployment projections, and the deployment is expected soon after the hydrogen refueling stations are constructed.

9 California Air Resources Board. *2016 Annual Evaluation of Hydrogen Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development.* July 2016. p. 10 with modification based on October 5, 2016 California Department of Motor Vehicle data. https://www.arb.ca.gov/msprog/zevprog/ab8/ab8_report_2016.pdf.

10 Available at www.energy.ca.gov/renewables/tracking_progress/documents/electric_vehicle.pdf

Figure 6: FCEV Populations and Comparison to Previously Reported Projections



Source: ARB

CHAPTER 4: Length of Time Required to Permit and Construct Hydrogen Refueling Stations

The length of time required to permit and construct a hydrogen refueling station varies from station to station. Station development typically follows the four phases described in Table 2. The Table 2 descriptions include the average length of time each phase has taken for the stations funded under Program Opportunity Notice (PON)-13-607 and that have completed the phase. Some station developers worked effectively and expeditiously, leading to operational stations at an accelerated pace. Refer to Appendix B for definitions of operational and open retail and for details on the testing that must occur before a station achieves open retail status.

Table 2: Typical Station Development Phases

Phases	Description
Phase One: Start of Energy Commission grant funded project to initial permit application filing	This phase begins when the grant funded project begins and includes site selection and site control, station planning, participation in pre-permitting meetings for confirmation of station design consistent with local zoning and building codes, and filing the initial permit application with the authority having jurisdiction (AHJ). Equipment ordering could occur during this phase depending on financial investment optimization. For the stations funded under PON-13-607 that completed this phase, it took on average eight months, with the quickest being the Coalinga station: 105 days.
Phase Two: Initial permit application filing to receipt of approval to build	This phase consists of AHJ review of the application and potential site reengineering/redesign based on AHJ feedback. Minor construction work could start prior to receiving approval to build depending on risk aversion, given that the approval may take a long time or never come to fruition. For the stations funded under PON-13-607 that completed this phase, it took on average eight months, with the quickest being the Riverside station: 61 days.
Phase Three: Approval to build to becoming operational	This phase includes station construction and meeting operational requirements: the station has a hydrogen fuel supply, passes a hydrogen quality test, dispenses at the H70-T40 pressure and temperature per standard (SAE J2601), successfully fuels one FCEV, and receives the occupancy permit from the AHJ. For the stations funded under PON-13-607 that completed this phase, it took on average six months, with the quickest being the San Jose station: 86 days.
Phase Four: Operational to open retail	In this phase, the station undergoes accuracy testing with the Division of Measurement Standards (DMS) and protocol testing with auto manufacturers (see Appendix B). Once the station has been confirmed to meet fueling protocol, the station is categorized as open retail. For the stations funded under PON-13-607 that completed this phase, it took on average two and a half months, with the quickest being the Saratoga station: 21 days.

Source: California Energy Commission staff

Average Station Development Durations

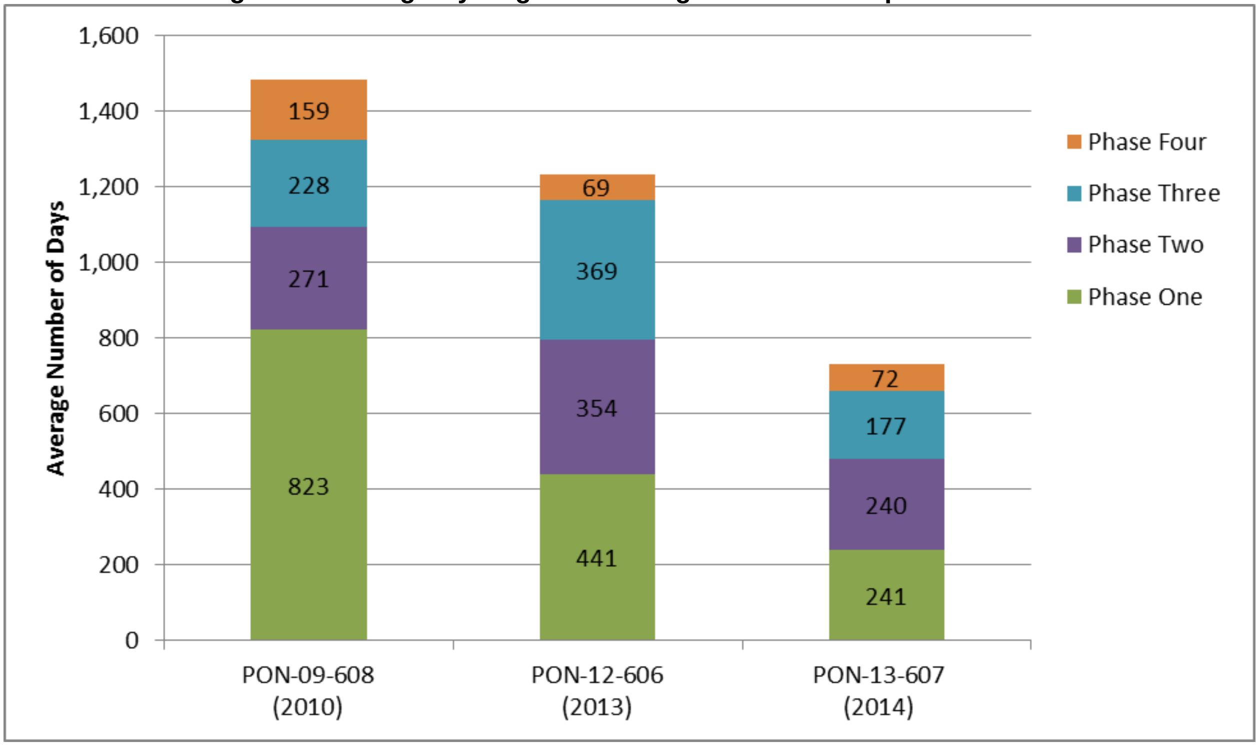
Figure 7 shows the average hydrogen refueling station development time with durations for the four phases. The numbers are averages of the stations that have completed each phase for each round of funding. Stations still in process are not included in the averages for the phases that they have not yet completed.

Although the average station development time for completed stations has been halved – from just over four years to two years – for stations funded under solicitation PON-13-607 compared to those funded under PON-09-608, the time for Phase Two (the initial permit filing to the receipt of approval to build the station) remains fairly constant across all PONs. The length of time for Phase One is what has changed most substantially and is influential on the later phases of development. The station that completed Phase One most quickly – the Coalinga station – is also the station that reached open retail status most quickly, finishing in roughly 17 months (507 days).

The length of time for Phase One was longest for stations funded under PON-09-608. Potential reasons for this may or may not include original station plans falling through that required some station locations to change, and some risk aversion about going into operation with few FCEVs on the road. Realizing Phase One was problematic for many initial projects, GO-Biz developed the *Hydrogen Station Permitting Guidebook*[11] to help developers understand the permitting process and share best practices for both AHJs and developers. With this resource, and with personal assistance from the GO-Biz ZEV Infrastructure Manager, station developers have been accomplishing Phase One more quickly in recent projects. The Energy Commission staff also meets with AHJs on an ongoing basis and presents the context for the station development projects in terms of how a station under consideration would complement the existing network, help decrease greenhouse gas emissions, and decrease criteria pollutants or smog-forming emissions. (See Appendix C for detailed analysis on social and environmental impacts of the hydrogen stations.) The Energy Commission's financial incentives are designed to motivate developers to complete stations quickly.

11 Governor's Office of Business and Economic Development. November 2015. *Hydrogen Station Permitting Guidebook: Best practices for planning, permitting and opening a hydrogen fueling station.* www.business.ca.gov/Programs/Permits/HydrogenStationPermitting.aspx.

Figure 7: Average Hydrogen Refueling Station Development Times



Source: California Energy Commission staff

Table 3 shows a summary of the number of stations that reached completion for the various station development phases as of December 5, 2016. For example, 26 of the 28 stations funded under PON-13-607 completed Phase One, taking on average 241 days. Of these, 16 stations progressed to open retail status (completing all phases). These 16 stations completed Phase Four in about two and a half months (72 days) on average.

Table 3: Average Duration of Hydrogen Refueling Station Development Phases

Energy Commission Solicitation / Contract	Phase One	Phase Two	Phase Three	Phase Four
PON-13-607 (2014)	**241 days** *26 of 28 stations*	**240 days** *21 of 28 stations*	**177 days** *17 of 28 stations*	**72 days** *16 of 28 stations*
PON-12-606 (2013)	**441 days** *4 of 7 stations*	**354 days** *3 of 7 stations*	**369 days** *2 of 7 stations*	**69 days** *2 of 7 stations*
PON-09-608 (2010)	**823 days** *8 of 10 stations*	**271 days** *8 of 10 stations*	**228 days** *7 of 10 stations*	**159 days** *7 of 10 stations*

Source: California Energy Commission staff

Factors Affecting Station Development Time

Several factors affect station development time, including changes of the station location, business environments and financial incentives, and project readiness. In some cases, developers changed subcontractors for station development and/or operation, or they changed the station location completely due to a business change at the station.

Changes in Station Location

As reported in the 2015 Joint Report, 30 percent (15 of 49) of station projects changed from their original locations, either due to a business change on the part of the gas station owner, the station operator, or new requirements that would alter the station economics. In some cases, a station developer completed a station design and applied for a permit, but lost site control due to a misunderstanding of an environmental requirement or traffic flow impact, or because of a change in site ownership. This 2016 Joint Report finds that six actual site changes occurred in 2016, including two that were included in the 15 station number given in the 2015 Joint Report.

To further decrease the likelihood of station location changes, GFO-15-605 requires grant recipients to complete two Critical Milestones before they are reimbursed for eligible expenses. Critical Milestone 1 requires the grant recipient to have held an in-person, preapplication meeting with the AHJ in the area where a station is proposed to discuss the station design and start obtaining permits to build and operate the station. Critical Milestone 2 requires the recipient to obtain and keep site control where the hydrogen refueling station is to be constructed. Together, these requirements should decrease the quantity of future site changes.

Production and Operation Incentives and Assistance

The Energy Commission offers financial incentives for accelerated permitting and construction under GFO-15-605; stations becoming operational within 20 months after a project is approved at an Energy Commission Business Meeting are eligible for a larger grant amount than those stations that take longer to become operational. PON-13-607 offered similar incentives. Although other factors may play a role in a station becoming operational, some stations met the financial incentives in PON-13-607 through accelerated permitting and construction. As of September 30, 2016, 19 stations met the financial incentives (for capital expenditures, O&M, or both) of PON-13-607.

Some regional air districts, most notably the South Coast Air Quality Management District (SCAQMD) and the Bay Area Air Quality Management District (BAAQMD), have also offered financial assistance to expedite the development of hydrogen refueling stations located in their jurisdictions. More information about these and other financial incentives is found in Appendix G.

Project Planning and Readiness

Hydrogen refueling station developers work closely with city and county project planners to envision the project, determine potential project acceptance, and make the project ready for the locale. The Energy Commission and GO-Biz often participate in planning meetings and public hearings to provide the perspective of California's hydrogen refueling network. The combination of experts provides recommendations for developers and, with collaboration, expedites results. The city and county project planners have provided invaluable assistance throughout the entire station deployment and network rollout. Detailed information on station planning, including discussion of the land-use ordinances and safety codes and standards that apply to hydrogen station development, is provided in Appendix E.

Also integral to the success of a station are timely equipment delivery, effective contract negotiations, quick and effective utility connections, conformance to applicable building, safety, and zoning codes, and, if needed, an ability and flexibility to customize a station to blend with local aesthetics. Readiness also includes the ability to size the station equipment accurately for the site. This ability requires analysis of the space needed for equipment, pedestrian traffic, and vehicular movement through the site – not only for light-duty vehicles to reach the hydrogen dispenser, but for heavy-duty vehicles to deliver hydrogen (if not generated on-site).

Planning that considers California Title 24 requirements for the Americans with Disabilities Act (ADA)[12] and that identifies and addresses any residual chemicals, leaks, and old equipment from previous fueling stations is most likely to result in a satisfactory station.

Since AHJs and communities often prioritize aesthetics according to the people who live in an area and businesses that operate there, the utmost attention is needed for the cost and the time needed to meet such requirements. For example, some value design, color, and appearance of the hydrogen refueling station. Others insist on updating the entire station where the hydrogen refueling station is planned leading to potentially unforeseen civil engineering costs and time to complete the station.

Outreach and education are also essential to the success of a hydrogen refueling station. The public acceptance of hydrogen refueling is often very influential to the success of a station and should therefore be planned for and carried out by the station developer, station owner, AHJ, auto manufacturers, Energy Commission, and GO-Biz. Station planning, readiness, and outreach are essential to California meeting the 100 hydrogen refueling station milestone; the contributions on the part of people at the local levels are key to successful station deployment.

12 California Code of Regulations Title 24 California Building Standards Code, Part 2 California Building Code, Vol I, Chapter 11B – Accessibility to Public Buildings, Public Accommodations, Commercial Building and Publicly Funded Housing.

Regional Readiness Planning

The Energy Commission provided funds to support the development of ZEV regional readiness plans. An objective of readiness planning is to build regional consensus around policy goals and objectives that will guide infrastructure planning, streamline municipal permitting processes, develop staff training, and promote FCEV use locally. Most early plans focused on Plug-in Electric Vehicles (PEVs), but more recent plans have addressed multiple fuel types including electricity, hydrogen, biofuels, and natural gas. A few have focused exclusively on readiness planning for hydrogen FCEVs.

Table 4 presents a summary of the regional agencies that have received Energy Commission grants to develop multiple fuel type readiness plans and/or hydrogen readiness plans, along with the corresponding grant agreement numbers and grant amounts. Figure 8 maps the areas where these regional readiness plans have been completed or are ongoing. The Energy Commission staff also provides assistance to regions in implementing their completed ZEV readiness plans.

Table 4: ARFVTP Funded Regional Readiness Plans Addressing FCEVs

Regional Agency	Region Covered (color in Figure 8)	Agreement Number	Funding Amount	Plan Type
Redwood Coast Energy Authority	North Coast: Del Norte, Glenn, Humboldt, Lake, Mendocino, Shasta, Siskiyou, Tehama, and Trinity Counties (gold)	ARV-14-055	$169,000	Hydrogen
		ARV-13-012	$300,000	Multiple Fuel Types
City and County of San Francisco, Department of the Environment	City and County of San Francisco (blue)	ARV-14-043	$111,495	Hydrogen
		ARV-13-053	$300,000	Multiple Fuel Types
City/County Association of Governments of San Mateo County	San Mateo County (blue)	ARV-13-018	$275,810	Multiple Fuel Types
Monterey Bay Unified Air Pollution Control District	Monterey Bay: Santa Cruz, Monterey, and San Benito Counties (green)	ARV-13-016	$300,000	Multiple Fuel Types
Santa Barbara County Air Pollution Control District	Central Coast: Santa Barbara, Ventura, and San Luis Obispo Counties (yellow)	ARV-14-038	$242,872	Hydrogen
		ARV-13-017	$299,910	Multiple Fuel Types
South Coast Air Quality Management District	Early FCEV Markets (purple dots)	ARV-13-056	$297,460	Hydrogen
San Diego Association of Governments	San Diego County (red)	ARV-13-013	$300,000	Multiple Fuel Types

Source: California Energy Commission staff

Figure 8: California Regions with ARFVTP Funding for Readiness Plans Addressing FCEVs

Source: California Energy Commission

Metropolitan Planning Organizations (MPOs) are also beginning to integrate ZEV goals and objectives into their regional transportation plans, which are the long-term blueprints for the regional transportation system. For example, in its *2016-2040 Regional Transportation Plan/Sustainable Communities Strategy*, adopted in April 2016, the Southern California Association of Governments (SCAG) notes that it has regular contact with hydrogen fuel cell industry partners and recommends policy to "continue to assist local jurisdictions in seeking grant opportunities for ZEV charging and refueling stations," including separate but complementary policy to the AB 8 directive to "encourage installation of 116 hydrogen stations by 2025, and market growth post 2025."[13]

In addition to planning at the regional level, cities are also beginning to participate in hydrogen infrastructure planning. Perhaps the best example of this is the city of San Francisco, which in May 2016 was selected by the U.S. Department of Energy (U.S. DOE) as the first Climate Action

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13 Southern California Association of Governments. *2016-2040 RTP/SCS Mobility Innovations Appendix*. pp. 2-3. http://scagrtpscs.net/Documents/2016/final/f2016RTPSCS_MobilityInnovations.pdf.

Champion to pursue hydrogen and fuel cell technologies for local transportation. U.S. DOE awarded the city of San Francisco and its partners funding to develop education and outreach programs to increase FCEV deployment and hydrogen infrastructure and to provide cost analyses for hydrogen fuel cell systems, hydrogen storage, and hydrogen production and delivery technologies.[14]

The work of local and regional agencies is evidence of the growing statewide awareness and support for FCEVs and hydrogen refueling infrastructure. Moreover, this work is a positive indicator that achieving more efficient and cost-effective deployment of hydrogen refueling stations is possible going forward with added insight from these partner agencies. The integration of ZEV goals and objectives in local and regional plans, in consultation with industry, stands to bolster the adoption of FCEVs and the success of ARFVTP-funded hydrogen refueling stations. Local and regional planning may also lead to new funding sources that will contribute towards reaching the 100-station milestone. The goal of these efforts is to achieve more ribbon cuttings, like the one shown in Figure 9, to celebrate more and more stations becoming operational.

Figure 9: Truckee Hydrogen Refueling Station Ribbon Cutting

Source: FirstElement Fuel

14 U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy. "Energy Department Announces Climate Action Champion, City of San Francisco, Embracing Hydrogen and Fuel Cell Technologies." http://energy.gov/eere/articles/energy-department-announces-climate-action-champion-city-san-francisco-embracing.

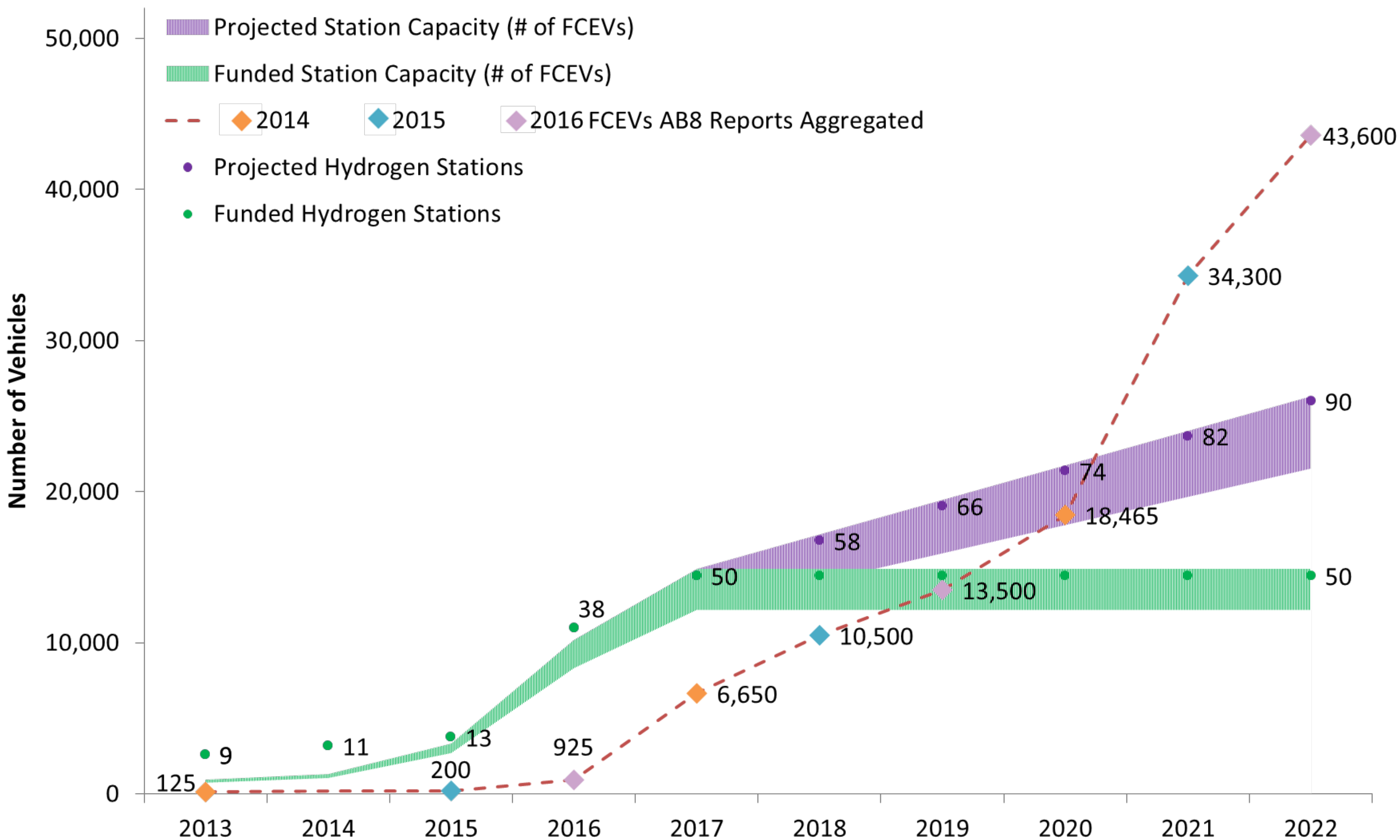
CHAPTER 5: Amount of Growth and the Timing of Growth of the Refueling Network

As discussed in Chapter 3, as of April 2016, 331 FCEVs were on California's roads, and as of October 5, 2016, there are 925 FCEVs. As shown in Figure 10, which updates Figure ES4 from ARB's 2016 Annual Evaluation, ARB's latest projections estimate that there will be 13,500 FCEVS in California by 2019 and 43,600 by 2022.

The highest growth in the FCEVs is predicted after 2020. Figure 10 shows, in purple, the projected number of open retail hydrogen refueling stations and the associated projected capacity in terms of the number of vehicles they could support. A fueling deficit is projected to occur around 2020, assuming existing station costs and capacity, and that ARFVTP annual funding remains \$20 million ("business-as-usual").[15]

15 California Air Resources Board. *2016 Annual Evaluation of Hydrogen Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development.* July 2016. p. 11. https://www.arb.ca.gov/msprog/zevprog/ab8/ab8_report_2016.pdf.

Figure 10: Projected Number of Vehicles Over Time



Source: ARB

Table 5 uses typical fuel consumption assumptions to show the amount of hydrogen that will be needed per day if the FCEV rollout proceeds according to the annual projections shown in Figure 10. Table 5 compares this “FCEV Fuel Demand” with “Total Nameplate Capacity” of the stations.

The Total Nameplate Capacity projections (kg/day) in Table 5 assume that future stations have a capacity of 180 kg/day. With this business-as-usual assumption, network growth from 50 stations in 2017 to 90 stations in 2022 will add 40*180 kg of daily capacity, or 7,200 kg/day. So Total Nameplate Capacity grows from 9,380 kg/day to 16,580 kg/day.

Table 5, based on Figure 10, confirms that today’s statewide network is capable of dispensing more than enough fuel to satisfy the demand from FCEVs for the next few years. Table 5 also reveals that a station capacity shortfall will occur around 2020 to 2021 (reporting is at year end, so a range is used), when the estimated need is 23,700 kg/day, but the estimated supply is only 15,140 kg/day. ARB’s 2016 Annual Evaluation provides more detail, including regional analyses, about these projections.[16]

Table 5: Stations, Fueling Capacity, and Projected Fuel Demand

	2017	2018	2019	2020	2021	2022
Quantity of Open Retail Stations	50	58	66	74	82	90
Total Nameplate Capacity (kg/day)	9,380	10,820	12,260	13,700	15,140	16,580
FCEV Fuel Demand (kg/day)	4,400	7,200	9,200	12,800	23,700	30,300

Source: ARB

Appendix D shows station dispensing and utilization information from the fourth quarter of 2015 and the first three quarters of 2016 for the network that is supporting FCEVs on California roads.

16 California Air Resources Board. *2016 Annual Evaluation of Hydrogen Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development.* July 2016. pp. 48-54. https://www.arb.ca.gov/msprog/zevprog/ab8/ab8_report_2016.pdf.

CHAPTER 6: Remaining Cost and Timing to Establish a Network of 100 Publicly Available Hydrogen Refueling Stations

The estimated remaining cost and timing to reach the 100-station milestone are roughly $125 million by 2024.

Both ARB's 2016 Annual Evaluation[17] and Table 6 assume eight stations per year can be funded, including O&M, with the $20 million allocation per year. This projection assumes the average time of about two years for station development (for stations completed under PON-13-607), as presented in Chapter 4. Using these assumptions, the 100-station milestone is anticipated to be achieved in 2024 with a cost of $125 million in addition to the $80.9 million for infrastructure that has already been allocated to fund the first 50 stations.

With full funding of $20 million in fiscal year 2021-22, 106 stations are estimated to become open retail by the end of 2024.

Table 6: The Amount of Cost and Time Needed to Reach 100 Stations

Funding Fiscal Year	ARFVTP Funding ($M)	Open Retail Stations	
		Number	Calendar Year
2015-16	20	58	2018
2016-17	20	66	2019
2017-18	20	74	2020
2018-19	20	82	2021
2019-20	20	90	2022
2020-21	20	98	2023
2021-22	5	100	2024
Total	125		

Source: California Energy Commission staff

17 California Air Resources Board. *2016 Annual Evaluation of Hydrogen Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development.* July 2016. https://www.arb.ca.gov/msprog/zevprog/ab8/ab8_report_2016.pdf.

Match Funding

Solicitations require match funding, and, in some cases, station developers absorb additional costs in excess of the match. Such costs, which often relate to civil engineering, landscaping, and aesthetic design, are sometimes unexpected. Table 7 lists the match funding requirements. Match funding combined with capital expenditure funding is the total station cost. One should consider match funding when considering total station cost.

Table 7: Match Funding Requirements

Energy Commission Solicitation and Contract	Match Funding Requirement	Total Match Funding from Recipients	Average Match Funding per Station
PON-13-607 (2014)	15% to 30%, depending on station operational date	$22,269,322	$ 767,908
PON-12-606 (2013)	35%	$ 7,234,257	$ 1,033,465
Energy Commission contract with SCAQMD (600-12-018) (2012)	0%	$ 974,516	$ 314,172
PON-09-608 (2010)	30% to 60% depending on station cost	$ 6,163,806	$ 616,381
Total		$36,641,901	$ 695,500

Source: California Energy Commission staff

Capital Expenditures

The 2015 Joint Report anticipates that capital expenditure costs will decrease between 2017 and 2025 because hydrogen station equipment costs should decline as equipment packages are standardized, larger stations are developed, equipment is produced at higher volumes, and station developers learn and apply more efficient integration and installation techniques. The level to which these costs are expected to decrease over time is shown in Figure 14 in the 2015 Joint Report. Appendix F includes capital equipment cost and O&M cost breakdowns.

This 2016 Joint Report maintains the same description of capital expenditure costs as the 2015 Joint Report*:* hydrogen station costs could decrease by about 50 percent by 2025 due to increased worldwide demand for hydrogen refueling stations.[18]

18 McKinney, Jim, et al. 2015. *Joint Agency Staff Report on Assembly Bill 8: Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California.* California Energy Commission. Publication Number: CEC-600-2015-016. pp. 4-5, 51, 93. http://www.energy.ca.gov/2015publications/CEC-600-2015-016/CEC-600-2015-016.pdf.

Operations and Maintenance (O&M)

O&M funding is provided to station developers that meet incentive deadlines. The objective of this funding is to provide financial support for eligible expenses such as rent, utility costs, labor, replacement parts, and maintenance. Appendix F includes scorecards that contain details about O&M costs, which can help future station developers understand the sources of O&M costs and potentially minimize them in the future. For example, a developer that connects to an existing building envelope to obtain the electricity rates of a larger facility may benefit; the O&M cost could be decreased. GO-Biz is examining electricity demand charges and the pricing of electricity and is working to get better electricity pricing for ZEVs as a whole, including hydrogen. Another approach could entail avoiding property rental costs by siting at a municipal organization.

Self-Sufficiency Framework

ARB and the Energy Commission are developing an analysis framework to understand and quantify financial opportunity-based decisions within the hydrogen infrastructure industry. The framework is intended to estimate the timing and cost of an approach to self-sufficiency; the analysis seeks to identify when the industry will find compelling financial opportunity in the prospect of hydrogen infrastructure development without requiring support from the state. The framework assesses opportunities from various perspectives to answer the question: "When will California's hydrogen refueling stations be self-sufficient?" As this framework is developed, it will help the analysis and determination of remaining cost and timing to reach the 100-station milestone in future joint reports. More details about the self-sufficiency framework are in Appendix A.

CHAPTER 7: Conclusions

Conclusions about coverage and capacity of the refueling network, FCEV deployment, the length of time to permit and construct stations, and the growth of the refueling network are summarized below. Based on equipment, design, engineering, project management, and overhead costs for hydrogen refueling stations, funded to date, this report concludes that about $125 million additional funding is needed to reach the 100-station milestone in 2024.

The Energy Commission's ARFVTP has already provided more than $100 million in total funding for hydrogen station development support with $80.9 million being invested specifically for 49 stations new or refurbished (or, upgraded) publically available hydrogen refueling stations.[19] Note: Three station upgrades will be pursued, instead of the original four stations that were planned so the total number of stations has decreased from 49 to 48.

Supporting hydrogen FCEVs and hydrogen refueling stations aligns with and supports Governor Brown's vision to encourage and increase the adoption of ZEVs to reach 1.5 million ZEVs by 2025. The Energy Commission and ARB should stay the course on hydrogen FCEVs and hydrogen refueling stations.

Coverage and Capacity of the Existing Hydrogen Refueling Station Network

- As of December 5, 2016, the ARFVTP-funded network of 48 stations in California consists of 25 open retail stations and another 23 stations that developers are working on to become open retail. Adding two ARB-funded stations that are open, non-retail, California's hydrogen refueling station network is composed of 50 stations.
- The coverage and capacity of California's hydrogen refueling stations that are open retail expanded more than ever before between December 31, 2015, and December 5, 2016. This growth was from 6 open retail stations to 25.
- The 48 ARFVTP-funded stations in the network have a fueling capacity of about 9,260 kg/day. Adding the two ARB-funded, open and non-retail stations in Harbor City and at CSULA, the 50 station hydrogen refueling network has a daily fueling capacity of about 9,380 kg/day, enough fuel for more than 13,000 FCEVs.
- The current hydrogen refueling network daily fueling capacity should satisfy projected FCEV demand for hydrogen until 2019.

19 McKinney, Jim, et al. 2015. *Joint Agency Staff Report on Assembly Bill 8: Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California.* California Energy Commission. Publication Number: CEC-600-2015-016. p. 14. http://www.energy.ca.gov/2015publications/CEC-600-2015-016/CEC-600-2015-016.pdf.

- The core early markets in the San Francisco Bay Area and the greater Los Angeles area are where most open retail stations are located, and these two areas are connected by the Coalinga station. The destination areas of Lake Tahoe and Santa Barbara are also being served.
- The importance of coverage and capacity considerations are underscored in GFO-15-605 through the use of the CHIT tool and market viability considerations as criteria in evaluating proposed station locations.

Fuel Cell Electric Vehicle Deployment

- As of October 5, 2016, DMV reports 925 FCEVs on California roads. There has been a dramatic increase recently – 331 FCEVs were registered as of April 2016 and nearly 200 as of October 2015.
- The 2016 Annual Evaluation projects that 13,500 FCEVs will be deployed in California in 2019, and 43,600 FCEVs will be deployed in 2022. These projections anticipate an increase in FCEV deployment over the 2015 Annual Evaluation projections of 10,500 FCEVs in 2018 and 34,300 in 2021.
- The updated projections of FCEV deployment are lower than previously reported for 2016-2018, but the expected FCEV deployment for 2020-2022 is higher.

Length of Time Required to Permit and Construct Hydrogen Refueling Stations

- As of December 5 2016, the shortest time from initial permit application for a station to receipt of a permit to build a station was just over three months (105 days), achieved by the Coalinga station. Coalinga was also the station that reached open retail status the fastest. Total station development time took roughly 17 months (507 days).
- The average station development time has fallen from just over four years (for stations funded under PON-09-608) to two years (for stations funded under PON-13-607). This indicates that faster development times are possible, and that the long development times observed in the past will not necessarily continue into the future.
- The overall pace of fuel availability or FCEVs fueling relies on additional considerations, including the pace of funding program development, FCEV auto manufacturer release schedules, and customer adoption rates.
- Station location changes cause substantive delays and the latest solicitation (GFO-15-605) sets forth Critical Milestones for preapplication meetings with AHJs and obtaining site control before any grant funding is paid.
- Financial incentives for capital equipment expenses and O&M continue to motivate station developers to complete their projects on time, as evidenced in more stations becoming open retail than ever before.
- Planning remains integral to the time required to permit and construct a station. Timely safety planning, equipment ordering and delivery, contracting, utility connection,

anticipation of local aesthetic requirements, fuel quality testing, dispenser evaluation, and compliance with standard fueling protocols all lead to stations becoming operational and open retail more quickly.

Amount of Growth and the Timing of Growth of the Refueling Network

- The highest growth in FCEVs is predicted after 2020.
- According to the ARB's 2016 Annual Evaluation, California will have a fueling capacity deficit around 2020. The 2016 Joint Report predicts the same deficit.
- With a business-as-usual assumption, the growth in the network from 50 stations in 2017 to 90 stations in 2022 will increase the network capacity to 16,580 kg/day, and this is not enough to meet the projected demand of more than 30,000 kg/day.

Remaining Cost and Time to Establish a Network of 100 Publicly Available Hydrogen Refueling Stations

- Funding from the ARFVTP in the amount of nearly $125 million remains necessary to establish at least 100 open retail stations by 2024.
- The private sector contributes, on average, $695,500 per station (match funding and other contributions). This is part of the total station cost but not part of the ARFVTP funds.
- The scorecards in Appendix F show rent as a significant amount of the daily operational costs and utilities a close second. GO-Biz is examining demand charges and pricing and is working to get better price signals for ZEVs as a whole, including hydrogen.

APPENDIX A: Self-Sufficiency Framework

The ARB and the Energy Commission are developing an analysis framework to understand and quantify financial opportunity-based decisions within the hydrogen infrastructure industry. The framework is intended to estimate the timing and cost of an approach to self-sufficiency. The analysis seeks to identify when the industry will find compelling financial opportunity in the prospect of hydrogen infrastructure development without requiring support from the state. The framework assesses opportunities from various perspectives to answer the question: "When will California's hydrogen refueling stations be self-sufficient?" Completing the framework requires extensive research and fact-finding before ARB and the Energy Commission will begin to estimate the potential timing of self-sufficiency for stakeholders and for the hydrogen refueling network, as a whole, but this appendix introduces the concept.

Figure A-1: Ontario Station Hydrogen Storage Containers

Source: Ontario CNG

The framework's general purpose and reasoning, along with illustrative discussion of the various business perspectives and value propositions are presented in this year's Joint Report. In the next report, the near-term self-sufficiency of stakeholders will be used to articulate qualitative vignettes that demonstrate the continued need for funds to reach the 100-station milestone. In future reports, the Energy Commission and ARB's joint goal is to have research and estimates completed for each type of individual stakeholder involved and to elevate the analysis to the level of the entire fueling network.

Value Proposition

Many analyses to date compare hydrogen cost to gasoline cost to project the FCEV consumer market growth and tied this to determination of self-sufficiency for the fueling station market. In these analyses, self-sufficiency of the hydrogen fueling industry is typically assumed to occur when hydrogen cost to the consumer is competitive with gasoline. However, self-sufficiency of the hydrogen refueling station market depends on business decisions made by *several* entities, including consumers; cost parity between hydrogen and gasoline is not always a direct factor in their evaluations of the value proposition posed by the hydrogen refueling business or may even be too stringent of a requirement. For example, a company may opt to invest in the hydrogen refueling station business while hydrogen is significantly more expensive than gasoline because the addition of hydrogen to their operations may present a favorable value proposition, even accounting for the additional cost. In other cases, the motivation may be to meet corporate social responsibility goals and the value of those goals, independent of costs of hydrogen and gasoline. Other entities, like municipal transit organizations, may also be motivated by non-economic value propositions as the communities they serve may expect them to meet social and environmental responsibility goals.

The proposed framework assumes there is some metric that determines whether self-funded investment in hydrogen infrastructure is a favorable venture. This metric may vary among different kinds of business entities in the hydrogen infrastructure industry. The proposed framework will therefore examine value proposition thresholds for various stakeholders and determine how long it will take before each metric reaches the threshold value, which will indicate that the entity decides investment in hydrogen refueling station business presents a value proposition worth pursuing. The framework thus helps estimate the timing until California's hydrogen fueling industry becomes self-sufficient. Synthesis of the analysis from various perspectives will then help the ARB and the Energy Commission estimate the potential duration and magnitude of state investments to help the hydrogen fueling station market successfully reach the AB 8 goal of self-sufficiency. The analysis could find self-sufficiency is achieved before or after the benchmark of 100 stations.

Table A-1 shows the overall question to answer for each entity: "How long will it be before the metric reaches the threshold value?" This metric defines a funding scenario for each entity's perspective and the scenario is used to determine the total cost. (Note: X in the thresholds in Table A-1 may be set to some calculated value or vary over a range to show sensitivities.)

Table A-1: Self-Sufficiency Framework

Value Proposition Entity	Value Proposition Metric	Previous Study?	Value Proposition Threshold	Affected by fuel cost difference?
Gas Station Owner	Revenue-opportunity costs (gasoline pump or other station services)	-	>$0, in X yrs.; X may be considered long-term	Yes
Industrial Gas Company	Revenue-opportunity costs (other hydrogen related ventures)	-	>$0, in X yrs.; X may be considered long-term	Indirect
Independent Operator	Traditional investment metrics, i.e., return on investment, and payback period	December 2015 AB 8 report	X yrs.	No
Auto Manufacturer	Cost differential of infrastructure investment vs. other sales-driving options to achieve target FCEV sales volume	-	X ≤ $0	No
Early Vehicle Driver	Fuel cost parity w/gasoline	University of California, Davis (UCD), others	X% premium, accounting for auto manufacturer-supplied fueling incentives	Yes
Mass-Market Vehicle Driver	Fuel cost parity w/gasoline	UCD, others	X% premium, not including auto manufacturer-supplied fueling incentives	Yes
Fleet Operator	Total cost of ownership parity w/gasoline	-	Equivalence or X% premium, including incentives available to fleet operator	Yes
Station Equipment Provider	Traditional investment metrics, like return on investment, and payback period	Variation on December 2015 Joint Report	X yrs.	No
Energy/Fuel Company	Revenue-opportunity costs (other fuel product ventures)	-	>$0, in X yrs.; X may be considered long-term	Yes
Public Agency	Monetary value of achieving policy goals, including quantified public health-benefits	National Academy of Sciences Report(s)	Within +/- X% of other state-funded options with similar goals	Indirect

Source: ARB

Framework Description

The framework will provide a nuanced view of the various business perspectives that evaluate whether pursuit of hydrogen fueling in their business operations is worthwhile. In recognition of important work to date evaluating the consumer market, the vehicle owner's perspective is also added to the analysis framework. It is also important to have this perspective as a control, or base case, against which the remaining perspectives can gain context. Some of the proposed perspectives (listed as the "value proposition entity") are already addressed in some prior works, but ARB and the Energy Commission feel many perspectives are not adequately covered in prior work.

ARB and the Energy Commission propose that for each perspective, there exists some individualized metric for the value proposition, specific to the entity's operations. For that metric, there is some threshold above which the entity decides a hydrogen fueling dispenser presents a value proposition worth pursuing. Using Energy Commission, ARB, and National Renewable Energy Laboratory (NREL) data and expertise in vehicle and station rollout projections and scenarios (for example, using the Scenario Evaluation, Regionalization & Analysis, known as SERA, model or other tool), each metric could be evaluated and a year determined in which the metric first crosses the threshold value. Cumulative station investment up to that point could be determined by an assumed/defined scenario of state cost share trends. This leads to determination of the potential cost and timing to achieve the goals of AB 8.

APPENDIX B: Station Status Terminology and Commissioning Details

This appendix discusses and defines some of the terminology used in this report to convey station status. It also discusses the commissioning that takes place to bring a station from operational status to open retail status. This discussion includes background information on the Hydrogen Station Equipment Performance (HyStEP) device, one of the new tools used to commission stations.

Station Status Terminology

The Energy Commission tracks the progress of station development from the time that a grant funding agreement is executed to when a station becomes open to the public, or “open retail.” The phases of station development are presented in Chapter 4, where they are discussed in the context of how long each phase has taken developers to complete. This appendix focuses on the terminology surrounding the general categories that describe the status of a station, as seen in the station maps in Chapter 2. There are four general categories to describe system status: planned, operational, open non-retail, and open retail.

The “planned” category describes any funded station that is in some phase of development, from planning, site selection, and permitting, to construction. Before a station opens to the public, it meets another threshold of becoming “operational.” Operational essentially means that the station has finished equipment installation and passed several technical requirements to prove it can dispense fuel. The operational designation is important for the Energy Commission and station developers in that it means a station has met grant agreement terms for the capital phase of the project, and the station developer can proceed into its O&M grant agreement phase (if applicable). Table B-1 lists the definitions of open retail and operational stations provided in the Energy Commission’s GFO-15-605.[20] However, the open retail definition in Table B-1 is related to technical requirements and does not fully describe the process that stations go through after becoming operational to reach the open retail status. This process is summarized in the next paragraph and later in this appendix, under Station Commissioning.

An operational station must complete commissioning before the station can begin selling hydrogen fuel to the public and be considered “open retail.” GO-Biz and the California Fuel Cell Partnership (CaFCP) work closely with auto manufacturers to define the commissioning process, which generally includes additional testing of the station. This process includes dispenser metering performance testing through the California Type Evaluation Program

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20 GFO-15-605 on Energy Commission website: http://www.energy.ca.gov/contracts/transportation.html#GFO-15-605.

(CTEP), administered by the California Department of Food and Agriculture's Division of Measurement Standards (CDFA/DMS). Additional fill testing using the point-of-sale (POS) terminal is performed by auto manufacturers and possibly by HyStEP, which is a relatively new device that was specifically designed to assist with commissioning. HyStEP is described more fully later in this appendix.

Once there is consensus by the auto manufacturers that the station is ready for their customers, and DMS has issued either a temporary use permit or certificate of approval for the dispenser(s), the station is deemed "open retail" and listed as such on the CaFCP's Station Operational Status System (SOSS)[21], which is an important tool for FCEV drivers to know if a station is open to the public and dispensing hydrogen fuel.

Table B-1: GFO-15-605 Definitions of Operational and Open Retail Stations

Operational Station	Open Retail Station
An operational station: -has a hydrogen fuel supply. -has an energized utility connection and source of system power. -has installed all station/dispenser components required to make the station functional. -has completed and passed a hydrogen quality test equivalent to the most recent version of SAE J2719. -has successfully fueled one FCEV with hydrogen. -dispenses hydrogen at the mandatory H70-T40 (700 bar) and 350 bar (if applicable). -is open to the public, meaning no obstructions or obstacles exist to preclude any individual from entering the station premises. -has all required state, local, county, and city permits to build and operate. -meets all the Minimum Technical Requirements of GFO-15-605.	An open retail station: -complies with SAE J2601 H70-T40 (the most recent version). -conforms to all applicable codes, regulations, and approved interface standards (fueling protocols, fuel quality, metrology, and permits). -uses a public point-of-sale (POS) terminal that accepts major credit, debit, and fleet cards. -is open to the public, meaning no access cards or personal identification (PIN) codes are required for the station to dispense fuel, and no formal or registered station training shall be required. -meets all the Minimum Technical Requirements of GFO-15-605.

Source: California Energy Commission staff

21 CaFCP's Station Operational Status System. http://m.cafcp.org/.

"Open Non-Retail" stations refer to demonstration stations funded by the ARB that are relatively small in hydrogen capacity and do not provide retail fueling services. ARFVTP funding has been used to upgrade some of these stations to open retail status, and a few other non-retail stations have been decommissioned. Two stations, one in Harbor City and one at California State University, Los Angeles (CSULA), fall into the open non-retail category.

Also see Appendix D of the 2016 Annual Evaluation for additional information on station status definitions.

Station Commissioning

FCEVs have driving range and fueling characteristics similar to most traditional gasoline powered vehicles. To obtain the 3–5-minute fueling times that today's drivers expect, stations must follow fueling protocols defined by SAE J2601. The standards help define fueling rates (in terms of vehicle tank pressurization rates) that account for conditions of a fueling, including initial tank pressure, temperature of the dispensed hydrogen, and ambient temperature. Following pressure ramp rates defined by J2601 ensures a safe fill is achieved and the longevity of the storage tanks onboard the vehicle is maintained.

The HyStEP device, developed through H2FIRST and funded by the U.S. DOE, is a portable trailer-mounted device used to test the ability of a station dispenser to adhere to these standardized protocols.[22] Figure B-1 shows the HyStEP device.

Operated by ARB, field engineers work with the HyStEP device to perform a matrix of test methods defined in CSA Hydrogen Gas Vehicles, Version 4.3 (CSA HGV 4.3). The tests detailed in CSA HGV 4.3 allow for standardized methods of testing the performance of hydrogen dispensers according to the requirements of SAE J2601. Following these test standards helps ensure that interpretation of data collected during validation testing is collected and analyzed consistently across devices. The HyStEP device has traveled more than 3,000 miles to test hydrogen refueling stations in Northern and Southern California.

After the dispenser of a station is tested by HyStEP, test results are shared, discussed, and vetted with the station operator/technology supplier. This is followed by a three-way discussion with ARB, station representatives, and an auto manufacturer station confirmation team. If the results are deemed satisfactory by the auto manufacturers, they may send their test vehicles and engineers to the station to perform the final confirmation tests before opening the station to the public.

22 U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy. H2FIRST: Hydrogen Fueling Infrastructure Research and Station Technology. http://energy.gov/eere/fuelcells/h2first.

Figure B-1: Photographs of the HyStEP Device

Source: ARB

(HyStEP includes three Type IV 70 MPa tanks and temperature and pressure sensors and can perform fill simulations of small, medium and large compressed hydrogen storage systems.)

The benefits of HyStEP testing are threefold:

1. As a universal validation tool, HyStEP has minimized the need for auto manufacturers to repeatedly send vehicles to test each station, thus reducing the overall time required to validate the fill performance of a station.
2. HyStEP allows ARB to act as a neutral government party to assist technology providers in fine-tuning the performance of station equipment. It also allows ARB the opportunity to better understand the current state of station compression, storage, and dispensing technology to be in a better position to help plan for future station performance needs.
3. HyStEP test results that are shared with industry can be used to verify fueling protocols and test procedures and assist in charting a path toward faster and more effective certification, inspection, and standards development. This will help streamline permitting and installation of future fueling stations.

HyStEP On-Site Station Testing

For a station that is properly prepared and operational (as defined in Table B-1), HyStEP testing can typically be completed in one work week (five days). During this period, the station operator is free to make hardware changes and software adjustments to fine tune the filling performance of the station. Anomalies are sometimes discovered through the HyStEP testing process, leading the station to order new equipment, resolve programming issues, or repair equipment. If repairs are necessary, a request is made for HyStEP to make a return trip to complete the testing matrix. Among the observed failures are communications and fuel temperature that causes the fills to miss SAE J2601 compliance. In pressure-related failures, some include missing 95 percent final state of charge, an average pressure ramp rate being too fast or too slow, and a target pressure set too high.

Analysis, Reports, and Follow-up Meetings

Following a week of testing, the ARB staff integrates the dispenser and HyStEP data, plots the 20 to 30 test fills, tabulates the fault and communication tests, creates a draft report, and sends the report to the station operator for review. During a data review call, the ARB and the station operator discuss station characteristics and confirm that the report presents station performance during testing accurately. Edits are made where necessary, the revised draft is sent to the auto manufacturers, and a second call is convened among ARB, the station operator, and the auto manufacturers. The report is reviewed in entirety, and questions are presented and answered. If the performance of the station is deemed satisfactory, the auto manufacturers schedule validation testing with their vehicles. Upon verifying satisfactory performance through auto manufacturer tests, the station operator is able to declare the station open for customer use. If results are not satisfactory, fixes are discussed, including a possible return of HyStEP for subsequent testing.

HyStEP Implementation Budget

In late 2015, the HyStEP Implementation program began with a budget of $400,000 to cover expenses of the CDFA fee for service through a metrologist, an expert technologist and scientist who studies standardized weights and measures. Through almost one year of operation, the program has a little above one-half of the funds remaining. ARB manages the deployment of HyStEP in California by providing a program manager, a field engineer, and a tow/supply vehicle, including all travel and expenses. HyStEP requires two operators; the ARB field staff is supplemented by a Metrologist III from the CDFA/DMS. The metrologist's fees ($150/hour) plus per-diem, travel, and expenses are covered by four $100,000 interagency agreements with SCAQMD, the Energy Commission, ARB, and the CaFCP through Bevilacqua-Knight, Inc.

HyStEP has performed tests at eight hydrogen refueling stations and accomplished 11 testing weeks. The average cost of one week of station testing is $12,000 per station (metrologist's fees only). Three of the eight stations required two weeks of testing. Significant non-testing expenses incurred early in the start-up of the program included out-of-state HyStEP training (at NREL) for two DMS metrologists. ARB expects current funds to allow station testing through most of 2017, and ARB has recently entered into the second year of a no-cost lease agreement with Sandia National Laboratories (SNL) to operate HyStEP through November 2017. Efforts are underway to obtain additional funding, and discussions are ongoing regarding sharing testing expenses with the station operator should a second week of testing be required.

California Type Evaluation – Hydrogen Gas-Measuring Devices

CDFA/DMS conducts metrology tests during station commissioning to certify the station can accurately sell hydrogen by the kilogram on a retail basis. Hydrogen refueling station dispensers must be evaluated for compliance with the California Code of Regulations (CCR), Title 4, Division 9, Chapter 1, Article 1, Section 4002.9 Hydrogen Gas-Measuring Devices (3.39).

For dispensers that are already "type-certified," meaning that a particular type of dispenser has already been certified by DMS, a "registered service agency" (RSA) which is a business that is registered with CDFA/DMS to install, repair, or service commercial weighing and measuring devices. Employees of a RSA that do the work on commercial devices must be licensed with CDFA/DMS and are known as Licensed Service Agents. They conduct necessary testing to ensure the newly installed dispenser meets the approved accuracy class.[23]

RSA testing must be witnessed by a local weights and measure official or DMS representative to obtain the required DMS temporary use permit and Certificate of Approval to sell fuel. The approximate cost of using an RSA service is $1,700 for a one-day test. Companies to date who have dispensers with Certificates of Conformance are Bennett Pump Company, CSULA, Equilon Enterprises LLC, and Quantum Fuel Systems Technologies Worldwide.

The hydrogen refueling stations also comply with a companion standard: SAE J2799: 2014, Hydrogen Surface Vehicle to Station Communications Hardware and Software. The CDFA/DMS uses the Hydrogen Field Standard for conducting tests on hydrogen dispenser designs to ensure they conform to one of the required accuracy classes to dispense hydrogen commercially by the kilogram and meet the specifications and tolerances adopted in the CCR for commercial hydrogen gas measuring devices. Hydrogen refueling station dispensers must be evaluated for compliance with CCR, Title 4, Division 9, Chapter 1, Article 1, Section 4002.9 Hydrogen Gas-Measuring Devices (3.39). Dispenser design types that meet the required criteria during testing are issued a California Certificate of Approval, which authorizes the installation and commercial use for that design.

23 California Department of Food and Agriculture, Division of Measurement Standards. *Registered Service Agency Program: Information Guide.* https://www.cdfa.ca.gov/dms/programs/rsa/rsaInfoGuide.pdf.

APPENDIX C:
Social and Environmental Impacts

Disadvantaged Communities and Pollution Burden

Table C-1 shows the number of ARFVTP-funded hydrogen refueling stations per county that are either in disadvantaged communities or in communities with high pollution burden according to the California Office of Environmental Health Hazard Assessment's CalEnviroScreen.[24] Disadvantaged communities have CalEnviroScreen scores of 76% or higher.[25] CalEnviroScreen scores are calculated using a quantitative method to evaluate multiple pollution sources and stressors, and vulnerability to pollution in California's census tracts.

Table C-1 shows that 11 ARFVTP-funded hydrogen refueling stations are in disadvantaged communities. In addition to these 11 stations, 10 stations are in communities with pollution burden scores of 76 percent or higher – for a total of 21 stations that are either in disadvantaged communities or in communities with high pollution burden. Communities with lower CalEnviroScreen scores could still have high pollution burden scores because CalEnviroScreen scores are made up of Pollution Burden scores and Population Characteristics scores. If communities have low Population Characteristics scores, such as vulnerable population characteristics, then the overall CalEnviroScreen scores could be lower even if a community had a high Pollution Burden score. Notably, some stations not in disadvantaged communities are within 1,000 feet of disadvantaged communities.

All the counties in Table C-1 are designated as ozone nonattainment areas, and 16 of these are designated as PM2.5 (particulate matter less than 2.5 microns) nonattainment areas.[26] FCEVs have zero tailpipe emissions and will displace mobile source emissions from conventional gasoline vehicles in these communities that need cleaner air.

Climate Change

Table C-1 shows the counties with hydrogen refueling capacity and the GHG reduction cost to the State in thousands of dollars per metric ton. In Table C-1, the 2016 carbon dioxide equivalent (CO_2e) savings for each station is distributed to nearby counties served by the station, using factors provided by ARB, to estimate the CO_2e savings for each county. An illustrative example of the capacity assignment process is shown in Figure C-1.

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24 California Office of Environmental Health Hazard Assessment. CalEnviroScreen Version 2.0. http://oehha.ca.gov/calenviroscreen/report/calenviroscreen-version-20.

25 Disadvantaged communities were defined as having a CalEnviroScreen score of 76% or higher for the purpose of this report, consistent with the California Environmental Protection Agency's *SB 535 Designation of Disadvantaged Communities*, www.calepa.ca.gov/EnvJustice/GHGInvest/Documents/SB535DesCom.pdf.

26 California Air Resources Board. State Standard Area Designations. https://www.arb.ca.gov/desig/statedesig.htm.

Table C-1: Hydrogen Refueling Stations by County with Social and Environmental Impacts

County	# of Stations in a Disadvantaged Community	# of Stations with Pollution Burden	2016 CO_2e Savings (metric tons)	2016 GHG Reduction Cost ($1,000/ metric ton)	2019 Projected CO_2e Savings (metric tons)
Alameda	2		23	$100	2,700
Contra Costa			3	$210	890
Fresno			140	$13	460
Los Angeles	6	5	360	$55	21,000
Marin			1	$110	65
Orange	1	3	390	$30	7,600
Placer			7	$240	25
Riverside	1		0	-	1,100
Sacramento			32	$65	1,300
San Bernardino	1	1	4	$280	480
San Diego			0	-	2,200
San Francisco			31	$110	2,000
San Mateo			21	$64	1,700
Santa Barbara			11	$150	180
Santa Clara		1	59	$76	5,200
Sonoma			0	-	840
Ventura			0	-	110
Yolo			1	$65	7

Source: California Energy Commission staff

This GHG reduction cost-effectiveness is calculated by dividing the State's capital equipment expense and the O&M costs of the hydrogen refueling stations in the particular counties by the 2016 CO_2e savings anticipated for those counties. The costs used in the calculation are only the State's portion and do not represent the all-in costs. These figures take into account the gasoline usage displaced by the use of the hydrogen and the GHG emissions from production and distribution of the hydrogen.[27] The Carbon Intensity (CI) values for renewable and nonrenewable hydrogen supplied by the station developers' applications to Energy Commission solicitations are used. The 2016 CI of 96.5 g CO_2e/megajoule for gasoline and the Energy Economy Ratio (a value representing the efficiency of hydrogen fuel compared to gasoline) of 2.5 are used.[28]

Table C-1 reflects the actual dispensing of hydrogen in the first three quarters of 2016. If nameplate capacities of the station were used, the cost-effectiveness would be even more favorable than presented and would fall between $1,122 and $2,902 per metric ton CO_2e saved. If the average station lifetime is assumed to be 10 years, then the cost-effectiveness would be

27 California Energy Commission. Solicitations for Transportation Area Programs. GFO-15-605, Attachment 13. http://www.energy.ca.gov/contracts/transportation.html#GFO-15-605.

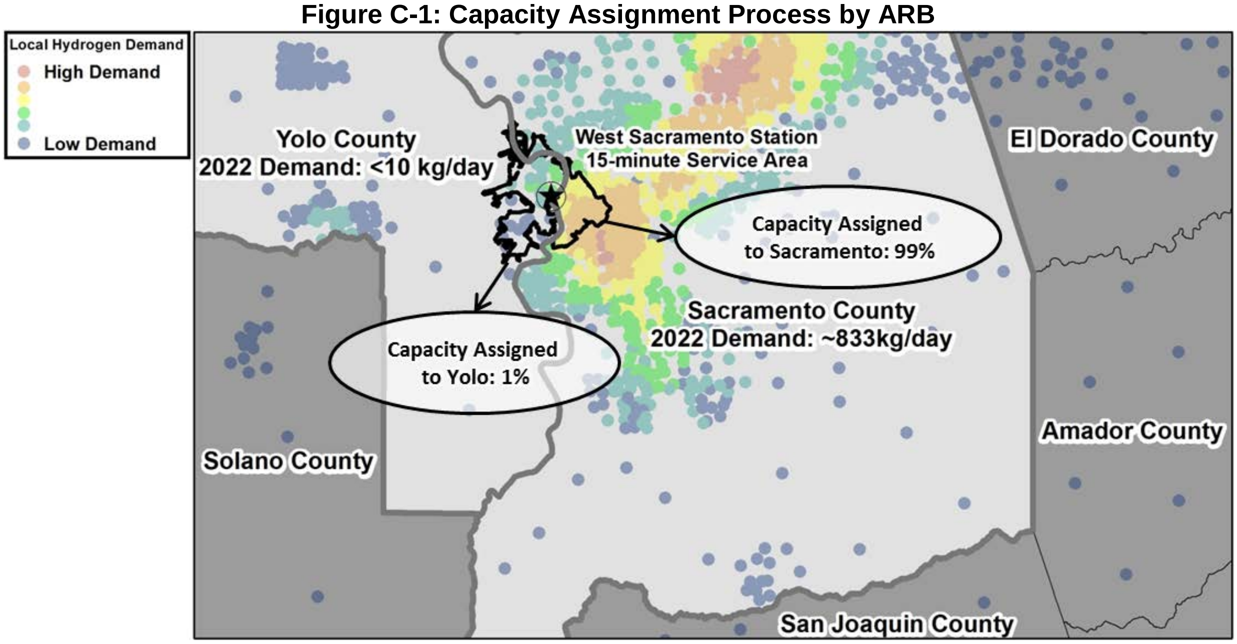
28 California Air Resources Board. Current LCFS Regulation. Table 1, p.32, and Table 4, p.45. https://www.arb.ca.gov/regact/2015/lcfs2015/lcfsfinalregorder.pdf.

about one-tenth of those values, in other words, \$122 to \$290 per metric ton CO_2e saved for 2016-2025.

The 2019 projected CO_2e savings (in metric tons) describes the avoided emission of carbon dioxide and other GHGs in 2019 based on ARB's estimates of FCEV deployment for that year and the resulting hydrogen demand. The 2019 CO_2e savings for each station is then calculated. The 2019 CI value for gasoline is 91.08 gCO_2e/megajoule, as published by ARB. The CI for gasoline decreases in 2019.[29]

The hydrogen projected to be dispensed in 2019 by each station and the temporary refueler funded by the Energy Commission is estimated based on the 2019 demand for hydrogen predicted for each county in California by the ARB. This anticipated demand is attributed to each station by using ARB's estimate of the proportion of the 2019 contribution of each station to the hydrogen supply in nearby counties. In Table C-1, the projected 2019 CO_2e savings are calculated using projected traffic patterns. If these exceed the nameplate capacity of the station, these are so limited to nameplate.

Figure C-1: Capacity Assignment Process by ARB



Source: ARB

29 Ibid.

Renewable Hydrogen

Senate Bill 1505 (Lowenthal, Chapter 877, Statutes of 2006) requires hydrogen refueling stations operating in California to dispense 33.3 percent renewable hydrogen. Stations receiving State funds must meet the requirement today, while ARB is tasked with adopting regulations to apply to all stations once the hydrogen fuel dispensed in California exceeds 3.5 million kilograms over a 12-month period. Before the adoption of SB 1505, industry was not required to sell renewable hydrogen. SB 1505 contributes to the reduction of greenhouse gas, criteria air pollutant, and toxic air contaminant emissions through the increased use of renewable hydrogen.

According to ARB's 2016 Annual Evaluation, the demand for renewable hydrogen is projected to reach 7,400 kg/day by 2022 for current and projected stations.[30] Based on station throughput and the projected delivery of stations in the "business-as-usual" scenario of 180 kg/day station capacity, 5,500 kg/day will be needed by 2022 to meet the 33.3 percent renewable requirement.

Some station developers informed the Energy Commission staff that their mission is to dispense more renewable hydrogen, meaning more sources for renewable hydrogen may be necessary.

Higher hydrogen demand implies there will be increasing opportunities to produce renewable hydrogen at larger scales, bringing costs down. Opportunities include grid-connected electrolysis or dedicated electrolysis at solar or wind facilities. Grid-connected electrolysis systems can operate dynamically and can serve as a means of converting otherwise curtailed renewable energy into a high-quality fuel for the transportation sector.[31,32] Other opportunities include converting biomass, biogas, or waste resource streams directly to hydrogen. An example of this is the trigeneration fuel cell facility formerly located at the Orange County Sanitation District, which could coproduce heat and electricity for use onsite, as well as hydrogen for vehicles.

30 California Air Resources Board. *2016 Annual Evaluation of Hydrogen Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development.* July 2016. p. 64. https://www.arb.ca.gov/msprog/zevprog/ab8/ab8_report_2016.pdf.

31 Eichman, Joshua, Aaron Townsend, and Marc Melaina. 2016. *Economic Assessment of Hydrogen Technologies Participating in California Electricity Markets.* National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy16osti/65856.pdf.

32 Melaina, Marc and Joshua Eichman. 2015. *Hydrogen Energy Storage: Grid and Transportation Services.* National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy15osti/62518.pdf.

Table C-2 lists the cost of 100 percent renewable liquid hydrogen as published in *Feasibility of the SF-BREEZE: a Zero-Emission, Hydrogen Fuel Cell, High-Speed Passenger Ferry* by SNL. The table shows that the difference in cost of renewable hydrogen can range from $3.25 to $16.15 per kilogram higher than natural gas-reformed hydrogen.[33]

Table C-2: Expected Cost of Liquid Hydrogen with Various Amounts of Renewable Content

Type of LH_2	Low	High
Natural gas, marginal renewable content	$5.43/kg	$7.40/kg
33% renewable content	$5.68/kg	$8.14/kg
100% renewable biogas and electricity	$8.68/kg	$21.58/kg

Source: Sandia National Laboratories

33 Pratt, Joseph W., and Leonard E. Klebanoff. *Feasibility of the SF-BREEZE: a Zero-Emission, Hydrogen Fuel Cell, High-Speed Passenger Ferry*. Sandia National Laboratories. SAND2016-9719. September 2016. https://www.marad.dot.gov/wp-content/uploads/pdf/SF-BREEZE-Ferry-Feasibility-Study-Report-by-Sandia-National-Laboratory-2.pdf.

APPENDIX D: Fueling Trends

Appendix D provides tables and figures that depict the actual use of California's hydrogen refueling station network. The data are obtained from the station operators and reported to the Energy Commission on a regular basis. The data aggregated in the following tables and figures are current as of September 30, 2016.

The following tables and figures report on station throughput and fueling pressures from the operational stations. This appendix includes dispensing information including the time of day and day of week of the fueling. Data are also provided by the type of fuel dispensed: hydrogen at a pressure of 70 mega Pascal (H70) or hydrogen at a pressure of 35 mega Pascal (H35). The data are compiled and analyzed by NREL. The Energy Commission expects the hydrogen dispensing to continue to grow commensurate with the FCEV deployment.

The first table in this section presents information about several statistics, including information about the retail prices of hydrogen. Because of this, this appendix also discusses hydrogen pricing trends relative to gasoline.

Quarterly Trends

Table D-1 reports on key infrastructure trend metrics throughout the reporting quarters, as well as the associated quarterly percentage change. These metrics include statistics based on the amount of hydrogen dispensed throughout the network and the price of hydrogen per kg.

The table shows that the amount of fuel dispensed has steadily increased over the past year. This increase can be shown from the average daily kilograms dispensed, average use utilization percentage, and total number of fuelings. The table also shows that the total unused capacity for the station network has increased by 480 percent (from 831 kg/day to 3,985 kg/day) from the year before. This is due to more stations in the network becoming open retail and able to offer a higher quantity of fuel. Although more stations have become open retail every quarter for the past year, thus increasing the nameplate capacity of the network, the average utilization has also increased from just 1.8 percent at the end of Q4 2015 to more than 8.0 percent at the end of Q3 2016. Thus, stations are being more highly utilized as more stations become available. This usage indicates a "network effect;" the addition of fuel availability in new locations can enable increased throughput at any station location because the network overall is more functional for the average driver.

The average fueling quantity per fueling event is consistent throughout the year. Because the average fueling quantity is 2.67 kg per fueling event, which is about half of an FCEV tank capacity, this could possibly show that FCEV drivers are not yet comfortable driving their FCEV until the tank is close to empty. Additional stations becoming open retail, expanding coverage, and adding redundancy to the network should resolve this issue.

Table D-1: Quarterly Statistics for the Network

Quarterly statistics	Q4/15	Q1/16	Q2/16	Q3/16	Annual average or total
Average daily kilograms dispensed	13	92	181	351	159
% change over previous quarter		+589%	+96%	+94%	
Average utilization (%)	1.8%	3.0%	4.5%	8.0%	4.3%
% change over previous quarter		+62%	+52%	+78%	
Average unused capacity (kg/day)	831	2,883	3,781	3,985	2,870
% change over previous quarter		+247%	+31%	+5%	
Total number of fuelings	504	3,240	5,732	11,408	79,541
% change over previous quarter		+543%	+77%	+99%	
Average fueling quantity (kg)	2.43	2.58	2.87	2.82	2.67
% change over previous quarter		+6%	+11%	-1%	
Total hydrogen dispensed (kg)	1,224	8,351	16,428	32,215	58,639
% change over previous quarter		+582%	+97%	+96%	
Maximum price of H70 ($/kg)	$ 17.68	$ 16.66	$ 16.78	$ 16.78	
Minimum price of H70 ($/kg)	$ 13.59	$ 12.85	$ 12.85	$ 12.85	
Sales-weighted price H70 ($/kg)	$ 15.43	$ 15.19	$ 15.18	$ 15.28	$ 15.25
% change over previous quarter		-2%	-0%	+1%	
Maximum price of H35 ($/kg)	$ 17.90	$ 16.62	$ 16.78	$ 16.78	
Minimum price of H35 ($/kg)	$ 14.01	$ 10.85	$ 10.85	$ 10.85	
Sales-weighted price H35 ($/kg)	$ 16.17	$ 14.46	$ 13.68	$ 13.36	$ 13.71
% change over previous quarter		-11%	-5%	-2%	
Sales-weighted price H2 ($/kg)	$ 15.45	$ 15.08	$ 14.94	$ 15.11	$ 15.07
% change over previous quarter		-2%	-1%	+1%	

Source: NREL

The price of hydrogen has stayed about the same throughout the last year, with prices ranging from $12.85 to $16.78 per kg at the end of Q3 2016. As more stations become open retail and there is a higher utilization of the stations, the price per kg of hydrogen is projected to drop to ranges competitive with the prices of gasoline.

Retail hydrogen prices are important to station operators, FCEV consumers, station developers, and auto manufacturers. For the station operator, retail sales at a given price are the primary means to recover costs incurred for operations, maintenance, and capital. For consumers, their perspective on hydrogen fuel prices may influence their decision on whether to purchase or lease an FCEV. During the first few years of vehicle introductions (2015-2020), hydrogen fuel retailers will likely not be able to charge prices that reflect the true economics of a station in a given year, as those prices would likely be unacceptable to most FCEV drivers. FCEV drivers are offered free fuel for the first three years of vehicle ownership or leasing, which is often paid for by the auto manufacturers. While the cost of hydrogen fuel is free for the first three years of ownership, it is a factor in FCEV sales. If hydrogen prices are too high, FCEV sales could become depressed, which could dampen future demand growth and reduce the rate of growth in revenue across the market.

From Energy Commission staff observations, a common price per kg of hydrogen is about \$16.50 at the end of Q3 2016. The energy density in a kg of hydrogen is equal to the energy density in a gallon of gasoline, but a fuel cell is roughly 2.5 times as efficient as a traditional internal combustion engine; \$16.50 per kg of hydrogen is equivalent to the price of \$6.60 per gallon of gasoline. Assuming that the average price per gallon of gasoline in California is \$3.50 per gallon[34], hydrogen prices would have to drop to below \$8.75 per kg to be competitive with gasoline.

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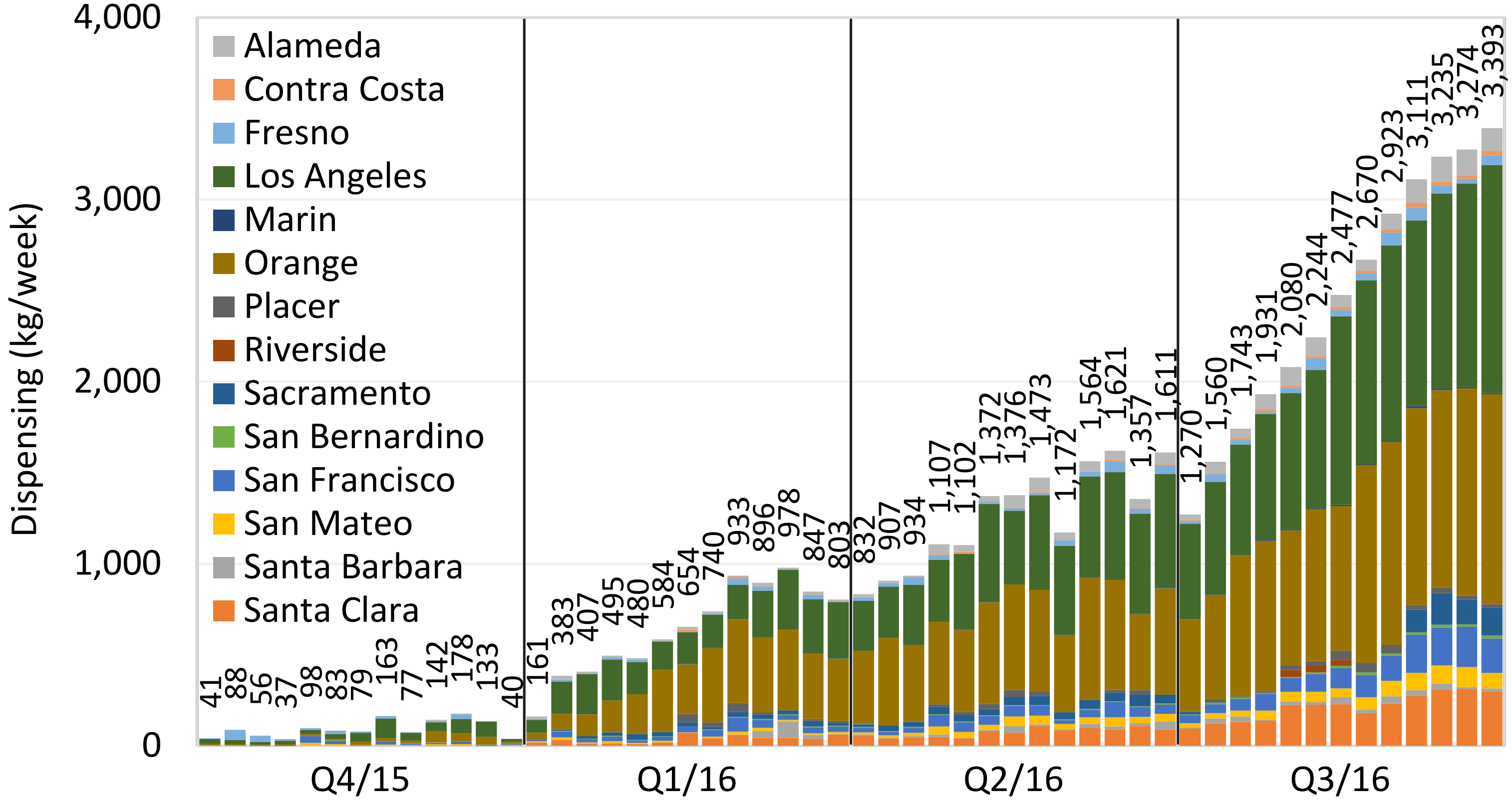
34 McKinney, Jim, et al. 2015. *Joint Agency Staff Report on Assembly Bill 8: Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California*. California Energy Commission. Publication Number: CEC-600-2015-016. http://www.energy.ca.gov/2015publications/CEC-600-2015-016/CEC-600-2015-016.pdf.

Weekly Dispensing and Utilization Trends

Figure D-1 shows the weekly average fuel dispensed, grouped by quarter and attributed on a county basis. New FCEVs and the associated increased use over time are the main reasons for the recent strong positive trend. This figure shows the fuel dispensed at both H70 and H35 pressures. The majority of dispensing is occurring at H70, and the next figure helps clarify this by presenting only the fueling done at H35.

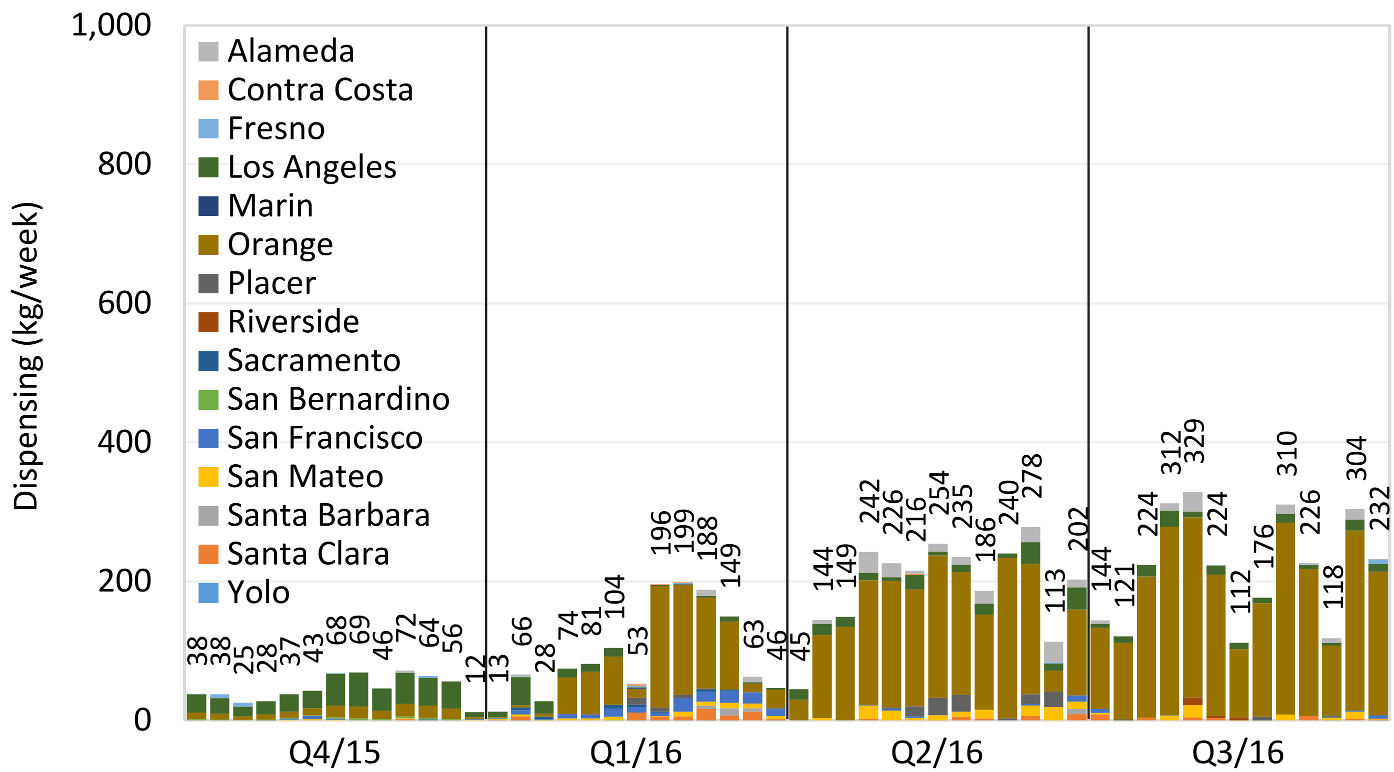
Figure D-1: Weekly Hydrogen Dispensing by County, H70 and H35



Source: NREL

Figure D-2 shows weekly average H35 fuel dispensed, grouped by quarter and attributed on a county basis. The relatively large amount of H35 dispensing occurring in Orange County is due to Orange County Transportation Authority (OCTA) and UC Irvine fuel cell buses refueling at the UC Irvine station. Besides these buses, there are a number of consumers of H35 fuel. Some older-model FCEVs, most notably the Honda FCX Clarity (not to be confused with the next-generation Honda Clarity that will be commercially available soon) use H35 fuel. Drivers of newer model, H70-capable FCEVs sometimes use H35 as a fallback if H70 is temporarily unavailable. Finally, there are nonvehicle consumers that use H35 to fuel devices in applications, such as light towers, portable generators, and cell phone towers.

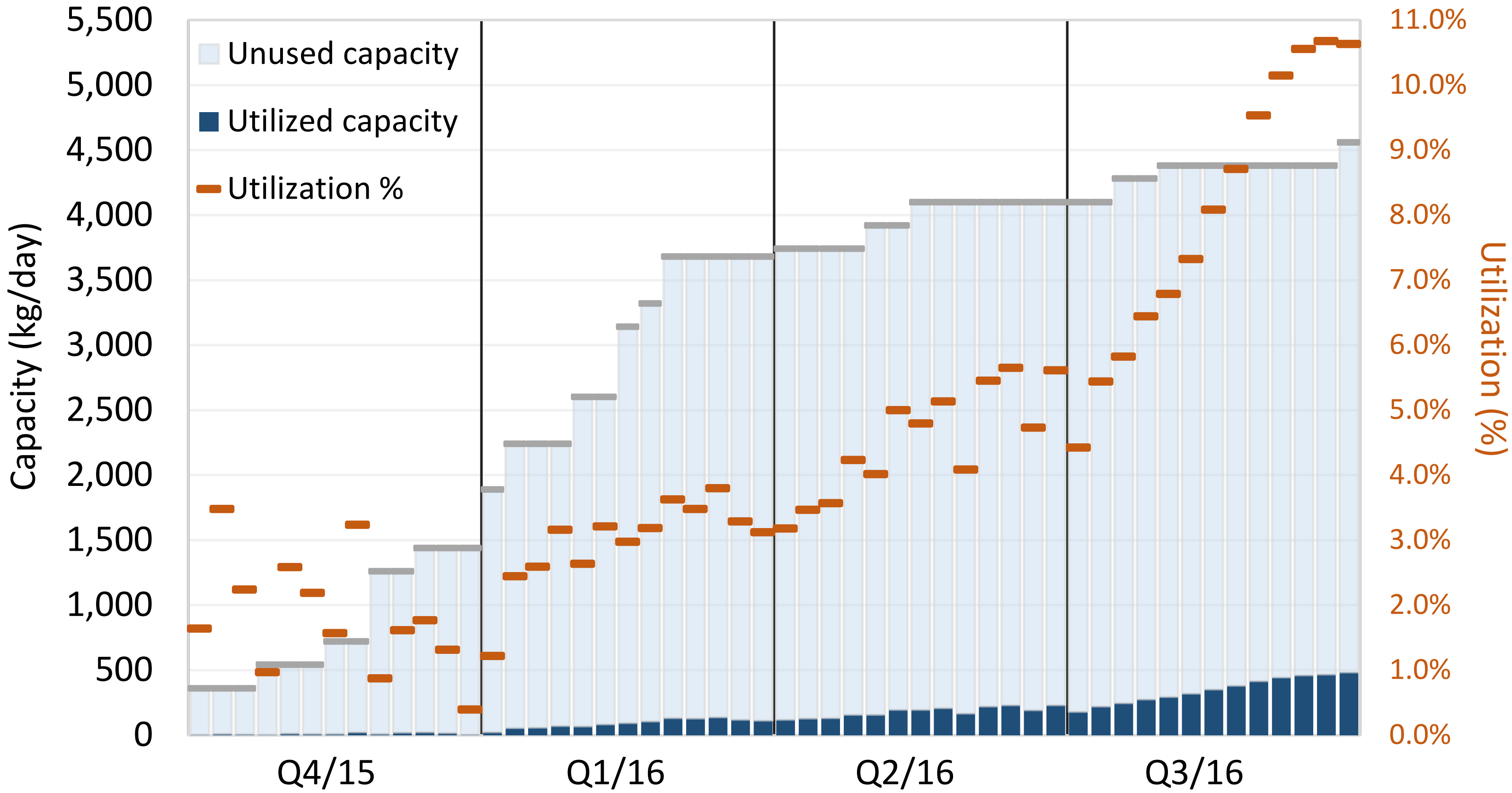
Figure D-2: Weekly Hydrogen Dispensing by County, H35



Source: NREL

Figure D-3 shows weekly average capacity of the network and the utilization of an increasing number of open retail stations. The increase is seen over the quarters. Both demand and capacity are growing. However, demand is growing at a faster pace, which yields an increasing utilization trend over time.

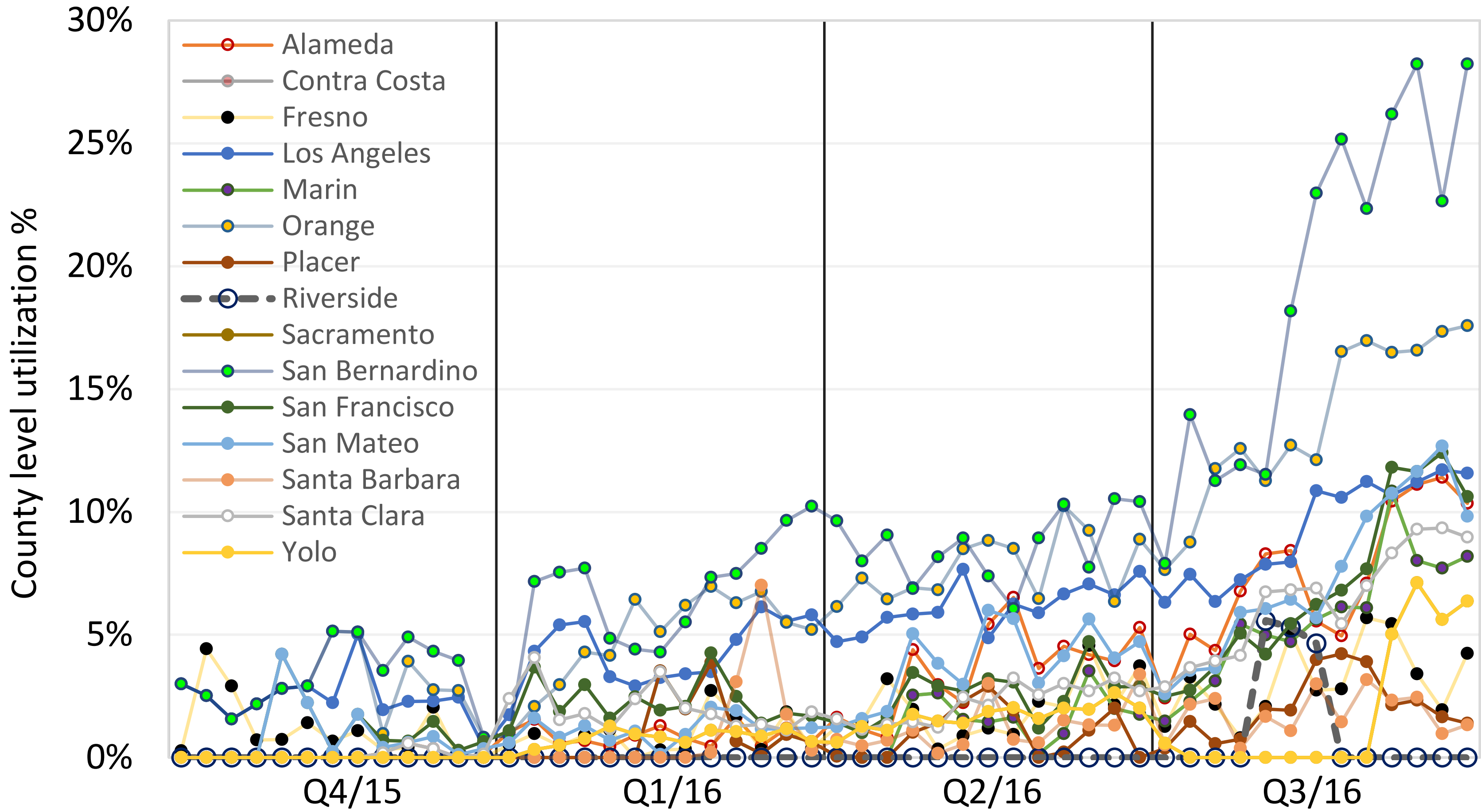
Figure D-3: Weekly Average Unused, Utilized, and Utilization Percentage of Network (kg/day)



Source: NREL

Figure D-4 shows demand increasing for all included counties and the percentage use relative to nameplate capacity for each county. Each county shows an initial spike in dispensing. This is an artifact of the open retail commissioning process, when fuel is used during testing but not sold.

Figure D-4: Weekly County-Level Dispensing Use Relative to Nameplate Capacity

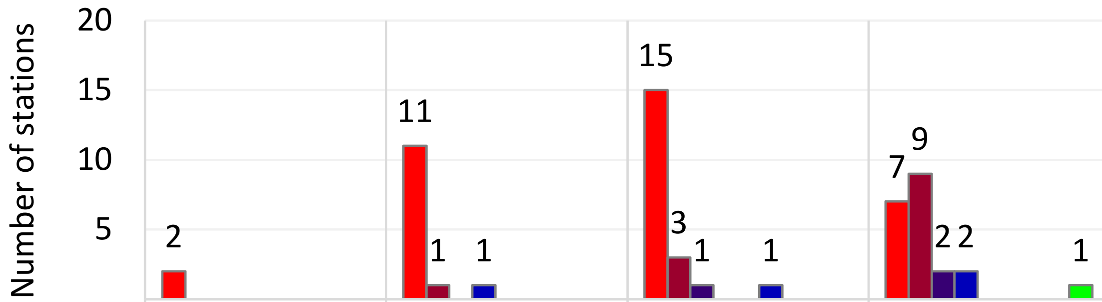


Source: NREL

Additional Utilization Analyses

Figure D-5 shows the use of each station based on the kilograms (kg) dispensed and the nameplate capacity of the station (dispensed kg/capacity kg). Station count by quarterly average utilization is shown. All stations are increasing in utilization. Some are performing significantly better than average, with stations moving above the zero to 5 percent utilization bin, where most stations begin. One station is at 40 to 45 percent use in quarter three of 2016.

Figure D-5: Station Count by Average Quarterly Utilization

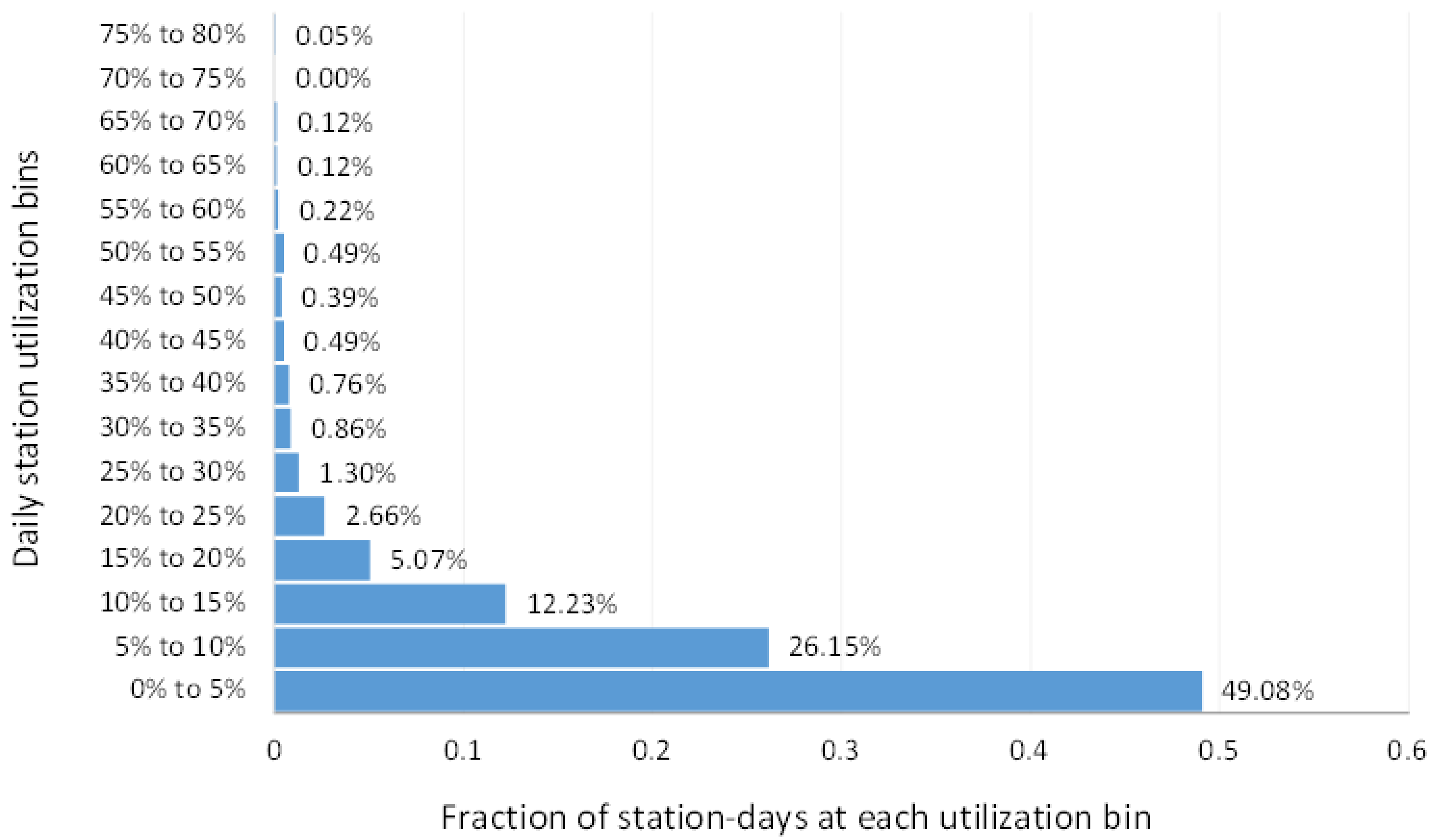


	Q4, 2015	Q1, 2016	Q2, 2016	Q3, 2016
0% to 5% utilization	2	11	15	7
5% to 10% utilization		1	3	9
10% to 15% utilization			1	2
15% to 20% utilization		1		2
20% to 25% utilization				
25% to 30% utilization			1	
30% to 35% utilization				
35% to 40% utilization				
40% to 45% utilization				1

Source: NREL

Figure D-6 shows the fraction of station-days spent at various utilization levels. While average utilization may be relatively low (zero to 5 percent), some stations experience significant utilization days (75 to 80 percent). This may be a cause for some stations to run out of on-site stored fuel between delivery cycles. The Energy Commission received reports in the third quarter of 2016 of stations running out of hydrogen gas.

Figure D-6: Distribution of Individual Daily Station Percentage Utilization



Source: NREL

Time-of-Day and Day-of-Week Trends

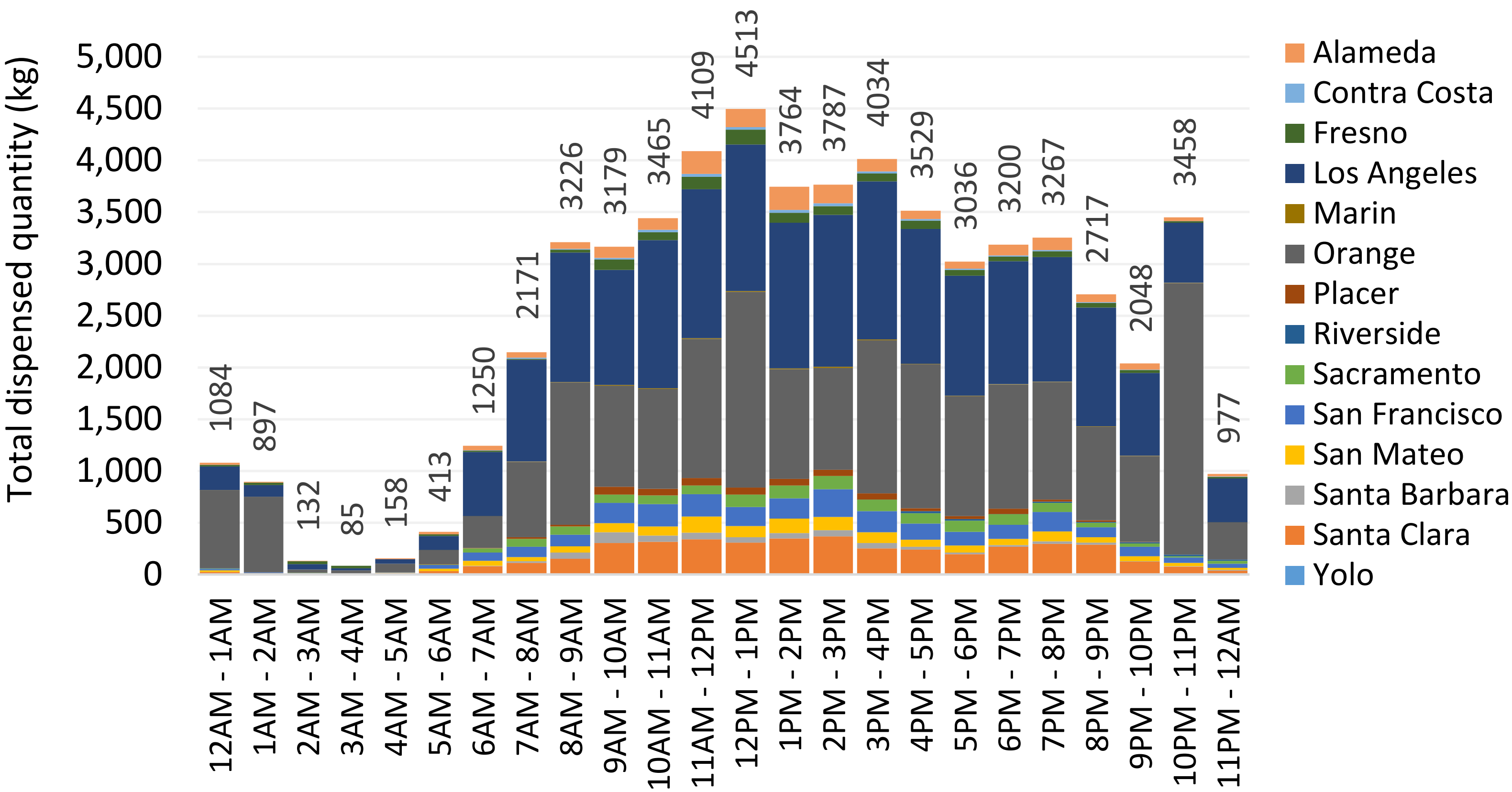
Figure D-7 shows that demand varies by time of day. The data are a collection of all dispensing. This information may serve as a guide for right-sizing station compressor and cascade storage to accommodate back-to-back refueling during peak hours.

As shown in Figure D-7, demand is highest during midday hours and could potentially lead to congestion if FCEV rollout yields too many cars for high-use stations, leaving customers to wait in line for fuel. The station developer is responsible for the station fueling plan that includes station refill based on demand.

The time-of-day fueling pattern shown below is different from what is typically observed for gasoline refueling. Peak times are expected to be in the early morning and late afternoon on weekdays, when the majority of people are going to or coming home from work.[35] This time-of-day pattern may change as the FCEV market continues to expand.

35 Chen, Tan-Ping. *Final Report: Hydrogen Delivery Infrastructure Options Analysis.* Nexant. DOE Award Number: DE-FG36-05GO15032. p. 53. http://energy.gov/sites/prod/files/2014/03/f11/delivery_infrastructure_analysis.pdf.

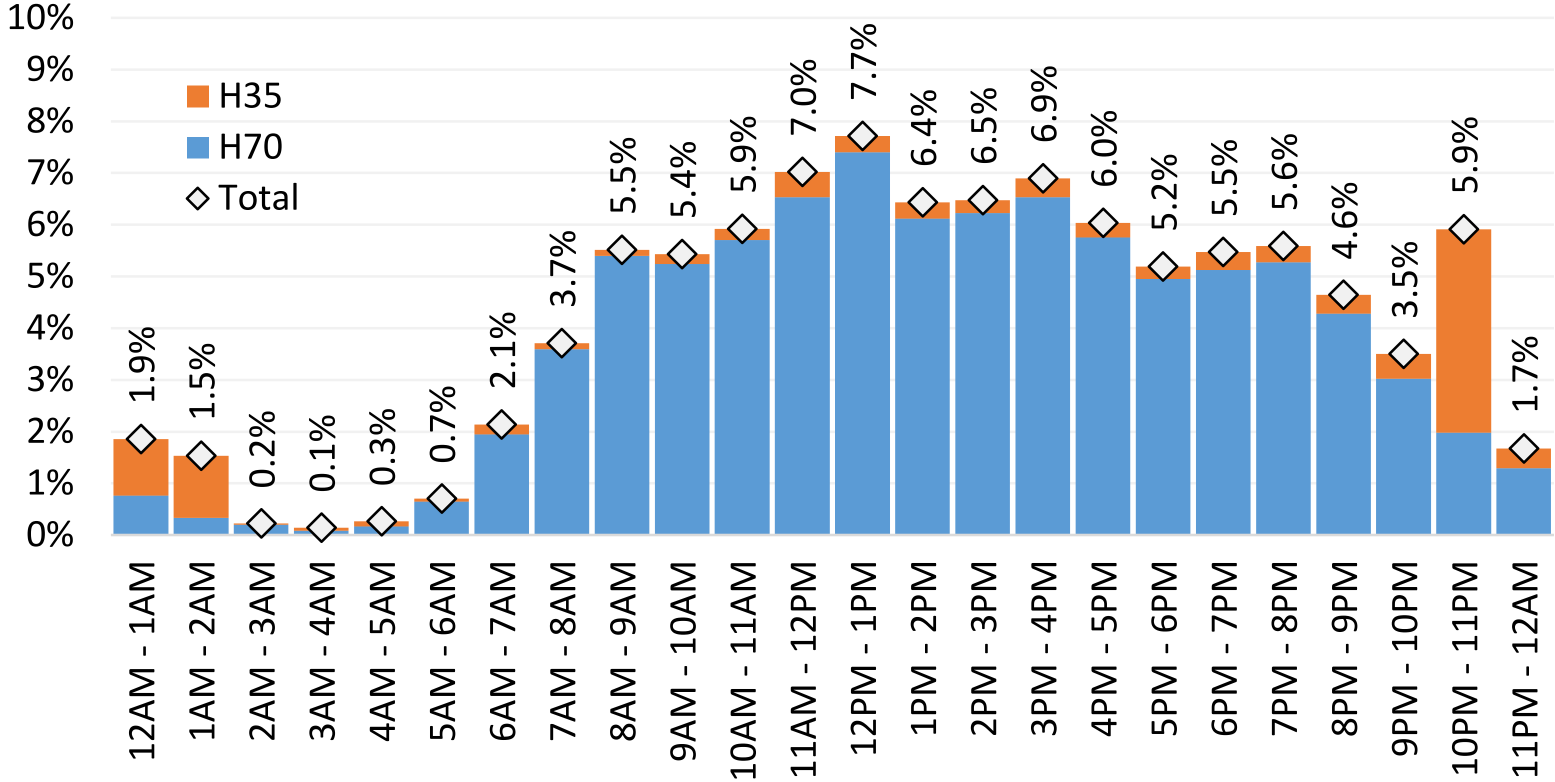
Figure D-7: Total Dispensing vs. Hour of Day by County (H70 and H35)



Source: NREL

Figure D-8 shows the fueling events by time of day at each station. The bulk of fueling events occur between 8 a.m. and 5 p.m. with the most fueling occurring over the noon hour. Figure D-8 displays distribution of daily dispensing between H70 and H35. The percentage of H35 fueling is relatively high over the late night/early morning hours because of fuel cell buses refueling after hours, when they are not in service.

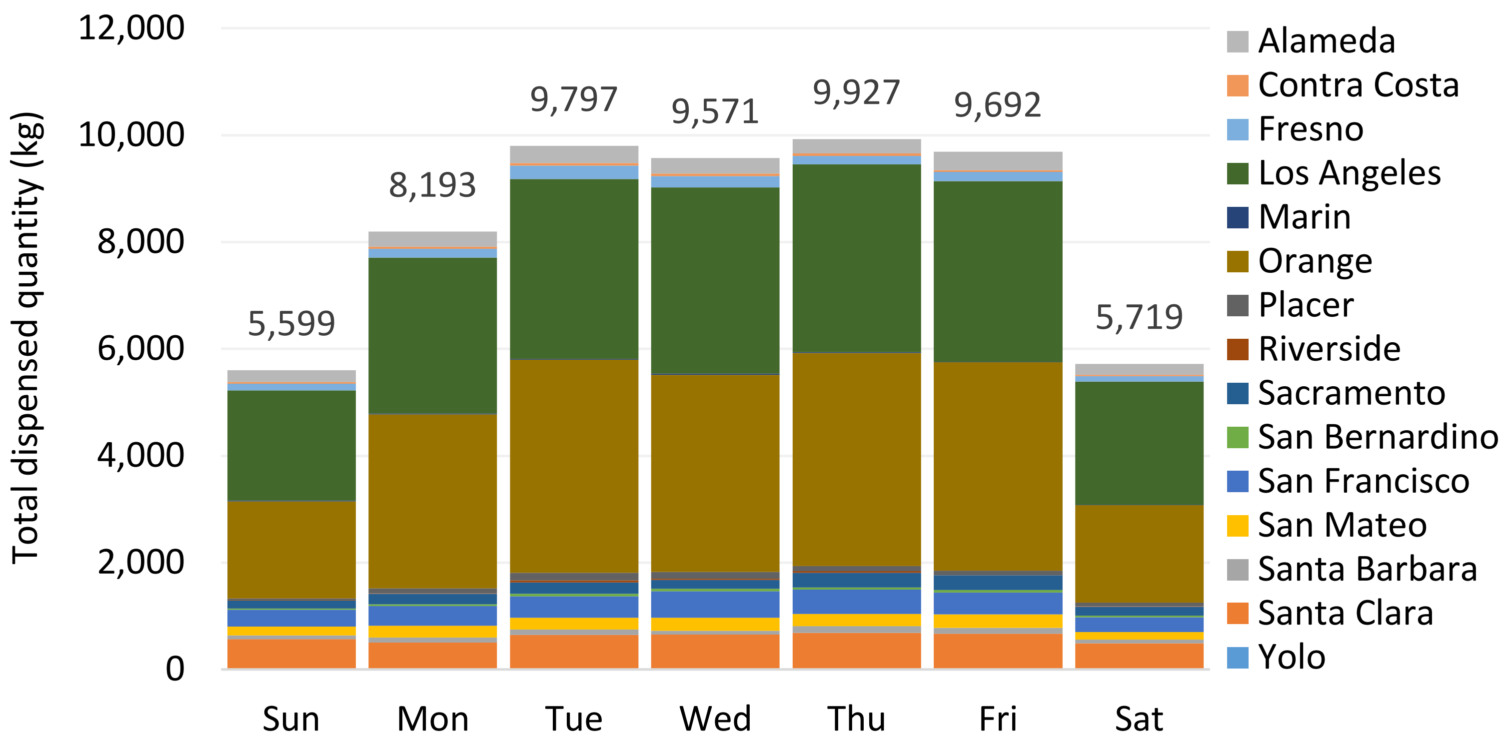
Figure D-8: Network Daily Dispensing Distribution (Percentage of Daily kg) (H35 and H70)



Source: NREL

Figure D-9 shows the variation in dispensing by day of week. On average, weekends have much lower demand, with total dispensing sometimes less than 6,000 kg per day. In the figure below, dispensing is shown in aggregate; this may help station developers select appropriate equipment to handle daily demand.

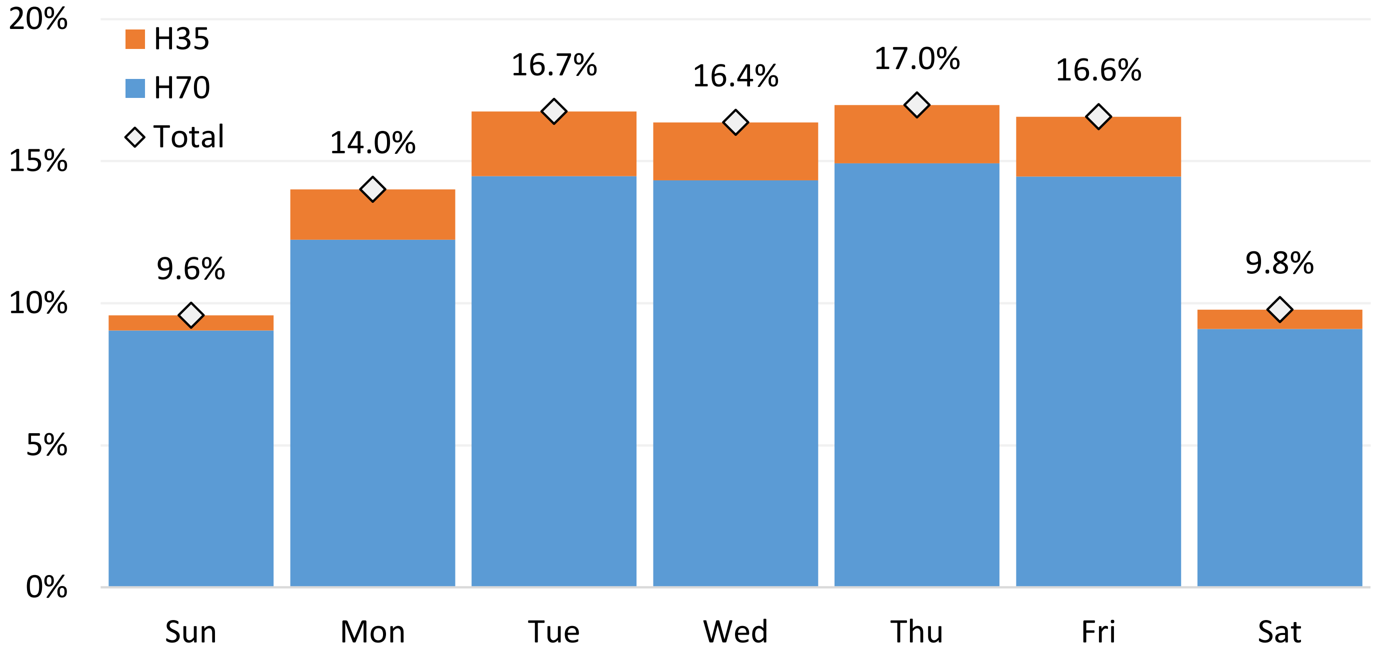
Figure D-9: Total Dispensing by Day of Week, by County (H70 and H35)



Source: NREL

Figure D-10 tracks the fueling events across the network by day of week. FCEVs predominantly fuel during the week instead of the weekend. These FCEVs are likely used by first adopters for commuting or running errands during the work week. Figure D-10 displays the distribution of weekly dispensing of H70 and H35. A common notion is that H35 demand would be countercyclical to H70 demand, meaning as H70 use increases, H35 fuel decreases. However, reported data show that the two demands coincide, meaning demand exists for both and trends appear similar.

Figure D-10: Weekly Dispensing Distribution (Percentage of Weekly kg)

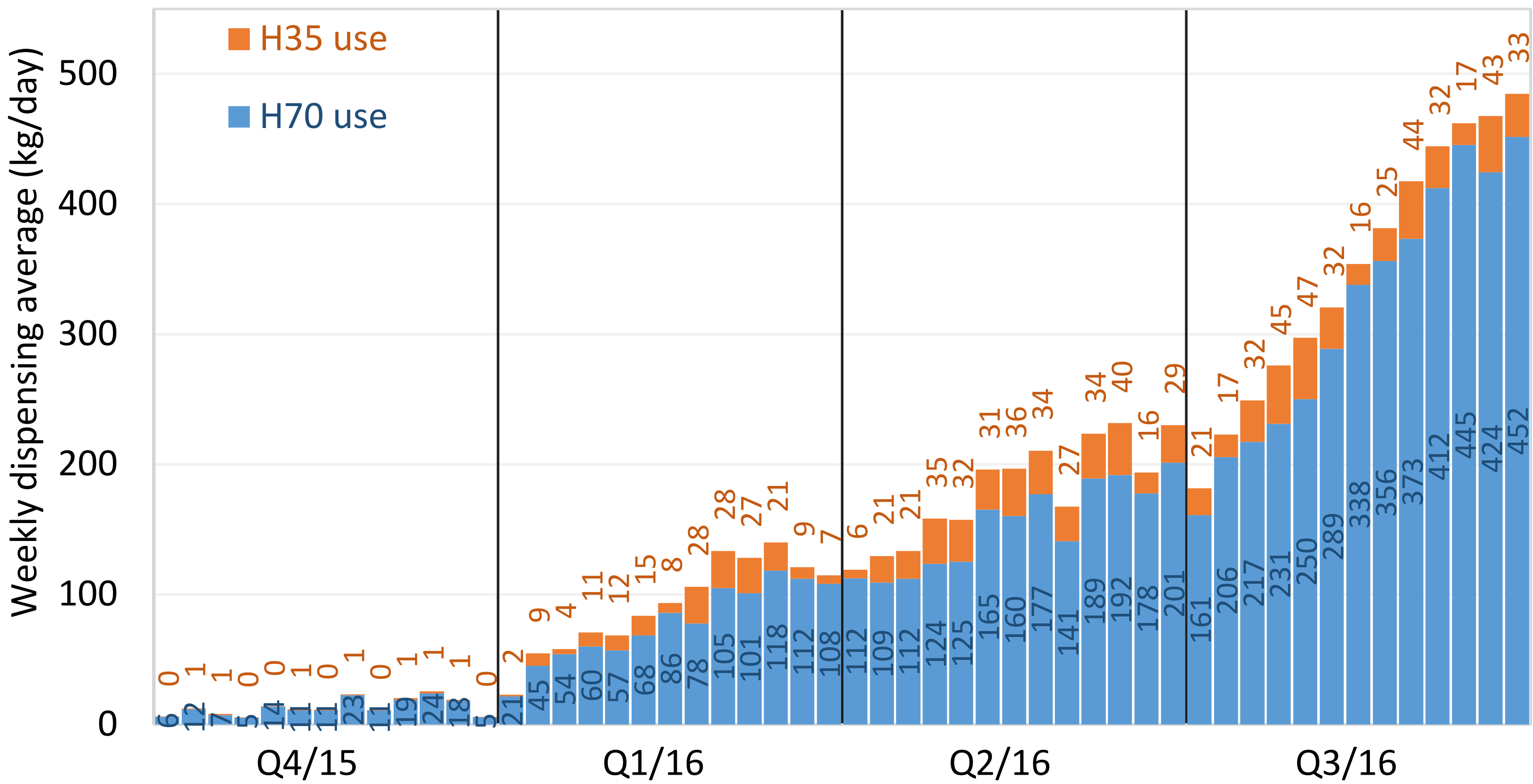


Source: NREL

H70 and H35 Trends

Figure D-11 compares the number of H70 versus H35 fueling events per week. The overall network, on average, fuels H70 89.8 percent of the time. The latest funding solicitation, GFO-15-605, requires applicants to provide H70 fuel; H35 is optional. Demand for H35 has not grown as fast as H70, especially in Quarter 3 of 2016.

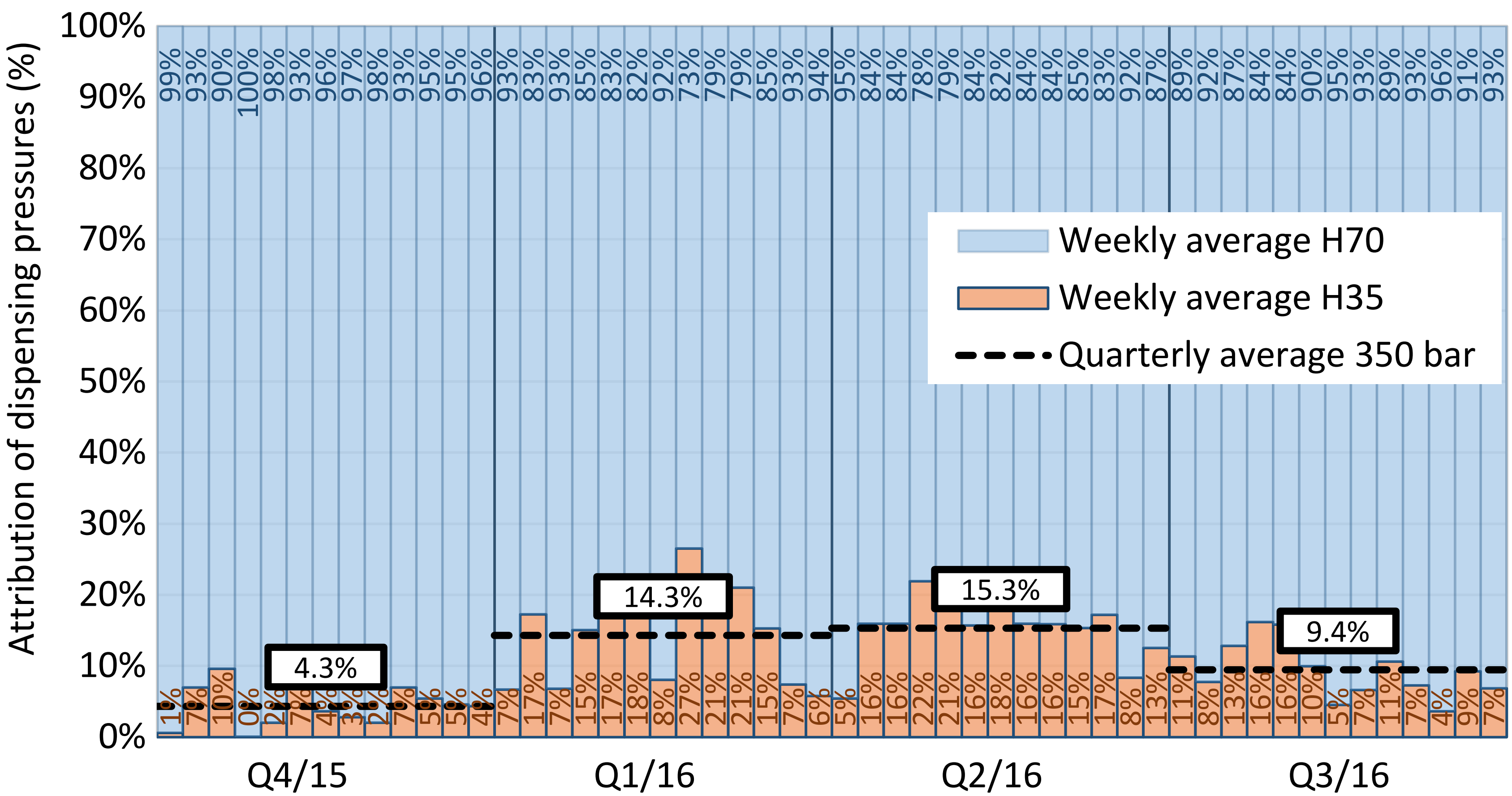
Figure D-11: Weekly Average Dispensing by Pressure



Source: NREL

In Figure D-12, the majority of fueling dispensed (on weekly average) is H70. Demand for both H35 and H70 grew, although in Quarter 3 of 2016, demand for H70 grew at a faster pace. Some of the growth in demand for H35 could be from fuel cell buses and from ancillary equipment such as portable generators and cell phone towers.

Figure D-12: Fraction of Fuel Dispensed by Pressure (Weekly and Quarterly)



Source: NREL

APPENDIX E:
Station Planning – Land-Use Ordinances and Safety Codes and Standards

Local land-use ordinances and state, national, and international safety codes and standards govern aspects of hydrogen refueling station design and determine if a site can accommodate a station. This appendix discusses how these land-use and safety regulations influence where a station can be built, and stresses the importance of working with AHJs to identify any planning or permitting issues early. This appendix also analyzes the amount of space (or the *footprint*) needed for the components of a hydrogen station, including hydrogen storage tanks and the dispenser.

Land-Use Ordinances

Land-use ordinances are codified into different municipal codes such as the zoning code and building code. The zoning code typically defines the uses that are allowed in every land-use zone within the municipality's jurisdiction. Zones typically include residential, commercial, and industrial categories, at minimum. The zoning code typically defines setbacks, such as the minimum distance that any structure (in general, not specific to hydrogen) must be from the lot lines and other building envelope restrictions, such as the maximum height, size, and/or density of structures.

Because hydrogen is relatively new in usage as a vehicle fuel, many jurisdictions' land-use ordinances do not address hydrogen refueling stations directly. Most jurisdictions have general automotive or motor vehicle fueling station uses defined in their zoning code, but there may be ambiguity about if hydrogen is allowed as the fuel type. The findings from an Energy Commission-funded report titled *San Diego Regional Alternative Fuel Assessment*[36] indicate the level to which this ambiguity exists. Nearly 70 percent of respondents said they did not know if their jurisdiction had zoning codes/ordinances specific to alternative fuels, while 23 percent said they did not, and only one respondent said yes, and that was specific to electric vehicle infrastructure.

When ambiguity exists, interpretation from a planning official in the AHJ is often required to determine if a hydrogen station would be allowed, or if an ordinance change would be required to allow it. The AHJ would also need to confirm if any discretionary land-use entitlements, such as a conditional use permit, site plan review, or zone variance, would be needed before the AHJ would give approval to build the hydrogen station.

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36 Center for Sustainable Energy. *San Diego Regional Alternative Fuel Assessment*. March 2015, p. 25. http://www.sandag.org/uploads/projectid/projectid_487_19864.pdf.

Some funded stations have encountered unique AHJ zoning code requirements. For instance, for the hydrogen station in the town of Woodside, the town's Planning Commission needed to make a use determination because its municipal code definition of "Service Station" was specific to gasoline.[37] Woodside took the opportunity to revise the "Service Station" definition to include diesel, ethanol, and other fuels.[38] For a different station – in the city of San Ramon – the city changed an ordinance to allow fueling without an attendant on site. These cases have underlined the importance of early consultation with the AHJ.

Safety Codes and Standards

The safety codes and standards that regulate hydrogen provide safe designs and processes for hydrogen, including storage tank design and location, vehicle fueling, and safety features.

The expanding use of hydrogen as an alternative fuel for vehicles has left local regulatory agencies in unfamiliar territory. The adoption of code and standards is a means through which these agencies provide a safe environment while allowing for new fuel types in their communities. A standard that is based on a national or state level creates a uniform application of regulations that promotes understanding and implementation.

California regulations regarding building standards are found in CCR Title 24 – California Building Standards Code.[39] These regulations typically set forth minimum requirements. A local AHJ such as a city or county may set more restrictive standards through ordinances. These ordinances may be based on local climatic, geographical, or topographical conditions. If an AHJ adopts more restrictive local ordinances related to fire safety, for example, then this AHJ would have requirements beyond those found in the California Fire Code (Part 9 of the California Building Standards code). Therefore, communication with the relevant AHJ about plans for siting a hydrogen refueling station is imperative, and this communication should occur as soon as a developer decides to site a station. Some AHJs lead preapplication meetings just to learn about the hydrogen refueling station network in California and to understand plans for their city or county.

In 2006, the National Fire Protection Association (NFPA) created a technical committee to address the issues created by the expanding use of hydrogen as a vehicle fuel. The technical committee created the 2011 NFPA 2 Hydrogen Technologies Code, which provides safety requirements for the generation, installation, storage, piping, use, and handling of hydrogen in compressed gas or liquid form.[40]

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37 Town of Woodside Planning Commission. April 1, 2015. Agenda Item 1 File Attachment. http://www.woodsidetown.org/sites/default/files/fileattachments/agenda_item_no._1r.pdf.

38 Town of Woodside Municipal Code. Section 153.005 – Definitions. http://www.woodsidetown.org/municipalcode/%C2%A7-153005-definitions.

39 The California Building Standards Code includes the California Fire Code and California Building Code, among others. Information about the California Building Standards Code is available on the California Building Standards Commission's website at http://www.bsc.ca.gov/Codes.aspx.

40 National Fire Protection Association. *NFPA 2: Hydrogen Technologies Code, 2016 Edition.* http://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards?mode=code&code=2.

The California Office of the State Fire Marshal within the California Department of Forestry and Fire Protection (CAL FIRE) has the responsibility of adopting building standards for fire and life safety (Health and Safety Code § 13108] and adopting the minimum requirements for the storage, handling, and use of hazardous materials, as defined, in the California Fire Code (Health and Safety Code § 13143.9). The Office of the State Fire Marshal adopted the hydrogen regulations in the California Fire Code, Part 9 of Title 24, including NFPA 2 as an adopted standard.

Adoption is done through the California Building Standards Commission in a triennial code adoption process with input from the stakeholders, interested parties, and the public. In 2014, California was the first state in the nation to adopt and approve the 2011 edition of NFPA 2.[41] The Office of the State Fire Marshal has already adopted the 2016 NFPA 2 edition through the Building Standards Commission process. It will become effective January 1, 2017.[42]

Station Footprints

Because codes and standards often define physical separation distances between hydrogen and other objects, they are a factor in determining the amount of space needed (that is, the footprint) for a hydrogen station.[43] To determine if a location could accommodate a hydrogen station, it is important for station developers to understand the separation distances required in the safety codes and standards used in the jurisdiction.

For a recent research program at SNL, researchers applied the separation distance and area requirements defined in the 2011 edition of NFPA 2 to existing gas station footprints to determine if enough space was present to satisfy the code requirements and add a hydrogen refueling station to the site.[44] The separation distances, particularly between hydrogen storage equipment and lot lines, building openings or air intakes, and parking, were considered for a sampling of 70 gasoline stations in California.

The SNL study discusses both liquid and gaseous hydrogen storage scenarios, and many of the separation distances are longer for liquid hydrogen. For instance, the distance between the specified gaseous storage tank and building openings or air intakes in the study is 24 feet, while the same requirement for the specified liquid storage tank of the study is 75 feet.[45]

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41 California State Fire Marshal. *Information Bulletin 14-010: Adoption of NFPA 2 Hydrogen Technologies Code for the Supplement to the 2013 California Building and Fire Code Effective Date.* November 2014. http://osfm.fire.ca.gov/informationbulletin/pdf/2014/IB_14010codesupplementNFPA2.pdf.

42 California State Fire Marshal. *Information Bulletin 16-004*: *Adoption of 2016 Edition of NFPA 2 for the 2016 California Fire Code*. March 2016. http://osfm.fire.ca.gov/informationbulletin/pdf/2016/IB_16-004_-_2016_NFPA_2.pdf.

43 Harris, A.P. Daniel E. Dedrick, Chris LaFleur, and Chris San Marchi. *Safety, Codes and Standards for Hydrogen Installations: Hydrogen Fueling System Footprint Metric Development*. Sandia National Laboratories, SAND2014-3416. April 2014. http://energy.sandia.gov/wp-content/gallery/uploads/SAND_2014-3416-SCS-Metrics-Development_distribution.pdf

44 Ibid.

45 Ibid. page 11.

Overall, the report concludes that somewhere between 18 and 44 percent of all the existing stations in the study areas could accept hydrogen, but it cautioned against applying these findings to other areas of the state or nation, given the differences in the built environment that exist throughout the country.[46]

The SNL report describes how the NFPA 2 is evolving from an expert opinion-based system to a science-driven system. Researchers completed the same evaluation on the 70 gas stations using a previous version of the code, NFPA 55 (2005)[47], and found that none of them could readily accept hydrogen. This finding indicates that the science-driven approach is producing newer safety codes and standards that are more favorable to hydrogen station development at existing gas stations.

Figure E-1: Fairfax Station

Source: ARB. Developer: Air Products and Chemicals, Inc.

Further, the SNL researchers note that separation distances can be reduced by incorporating fire barrier walls or insulation (for liquid storage) into station design. Moreover, the siting process is often flexible with the AHJ, in which the particular site is analyzed in relationship to surrounding land uses, and code applicability and possible mitigation measures are determined in an iterative process.

Using the SNL report method as a starting point, Energy Commission staff ran a similar evaluation: some gas stations in Northern California were analyzed using NFPA 2 separation distances to determine whether a hydrogen footprint could fit. The Energy Commission study focused on gaseous hydrogen storage and the separation distances between public streets and alleys (24 feet), buildings (10 feet), and building openings (24 feet). Of the stations studied, some could possibly accommodate hydrogen, with some caveats (for instance, an existing driveway might need relocation, or parking spaces could be converted to be part of the hydrogen station footprint). Taking a conservative approach, roughly 13 percent of the gas stations evaluated are viable, with a possible range up to 63 percent if code interpretation were relatively permissive and minor site alterations and compact designs were used.

The SNL and Energy Commission studies do not reflect all jurisdictions; they underline the importance of station developers conducting site evaluations in terms of these NFPA 2 distance

46 Ibid. page 18.

47 National Fire Protection Association. *NFPA 55: Compressed Gases and Cryogenic Fluids Code, 2005 Edition.* http://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards?mode=code&code=55

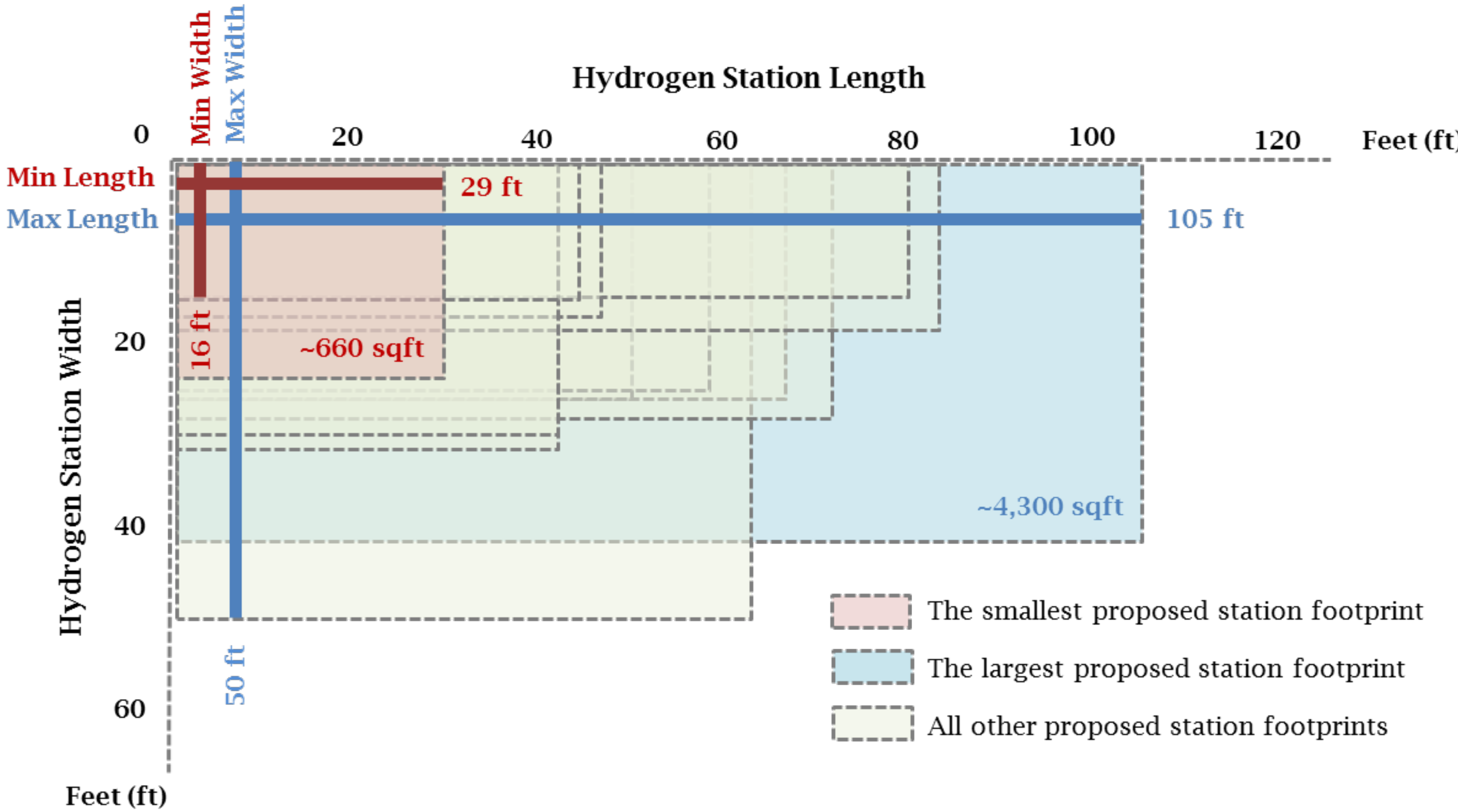
requirements to have a good idea, early in site selection, if particular sites are good fits for hydrogen.

The Energy Commission collected footprint information provided by applicants for 38 stations proposed in three previous Program Opportunity Notices (PONs). Figure E-2 demonstrates the range of square footage designated for hydrogen refueling equipment: width from 16 feet to 50 feet and length from 29 feet to 105 feet, and the area ranging from 660 to 4,300 square feet. Proposed stations using liquid hydrogen storage tend to require more square footage than those with gaseous hydrogen storage, which is not unexpected due to the longer separation distances described above. However, when also considering nameplate capacity, the liquid storage stations are actually about the same size – and in some cases smaller – than gaseous storage stations on a square-foot-to-kilogram basis.

The total site area – meaning the dimensions of the land parcel including any other improvements, such as gasoline refueling canopies, convenience stores and any other buildings, parking, and space for vehicular circulation – ranged from 11,600 to 99,600 square feet.

While the Energy Commission data collection is ongoing, the data collected thus far reveal that the hydrogen footprints shown in Figure E-2 tend to be less than 10 percent of the overall site footprint, a possible indicator of how the need to separate hydrogen from other physical objects can create the need for an overall site footprint that is much larger than just the hydrogen infrastructure (storage tank, compressor, chiller, dispenser, and so forth). However, the proposed footprint dimensions have been decreasing on average over time, from PON-09-608 to PON-13-607 (with the caveat that the proposed footprints may differ from what is ultimately built). Figure E-2 does not include NFPA 2 setbacks. It is possible that, as codes are updated further and designs are streamlined, the hydrogen station footprint may continue to shrink, and existing gas station sites that are not considered viable could become so.

Figure E-2: Hydrogen Station Equipment Footprints from Sampling of Proposals



Source: California Energy Commission staff

Other References

Several resources exist to help station developers make sense of the various codes and standards that apply to hydrogen station development. The GO-Biz collaborates with station developers and AHJs to streamline the planning and permitting process, and GO-Biz also developed the *Hydrogen Station Permitting Guidebook*[48] as a resource for both AHJs and developers. Other resources include the U.S. DOE Hydrogen and Fuel Cells Program at www.hydrogen.energy.gov, U.S. DOE's Alternative Fuels Data Center at www.afdc.energy.gov, and the U.S. DOE-supported Hydrogen Tools website at h2tools.org.

Standards are essential to the fueling protocols and physical characteristics of the stations, including safety and component interoperability. The estimated cost of purchasing fueling and safety standards for a typical hydrogen refueling station is $1,000. As updates to the standards are promulgated, the new standards must be purchased. The Energy Commission maintains a set that is accessible to the public. Some licensing fees may be affiliated.

Siting at Existing Gas Stations and Stores

Figure E-3: Costa Mesa Station

Source: FirstElement Fuel

One factor in hydrogen refueling station siting that can hinder timely development is the nature of the gas station industry. Most gas stations in the United States are owned by small businesses, with 58 percent of the convenience stores selling fuel being owned by single-store operators.[49] Said another way, there is a good chance that a hydrogen refueling station developer will be working with a different site owner on each station project.

This means that there is often a corresponding learning curve on each project to build the gas station owner's knowledge of the development process and the applicable planning, building, and safety codes. Delays may also arise from having to negotiate the lease agreement terms with a different owner on each project.

One opportunity that hydrogen refueling station developers may want to pursue to expedite development is building relationships with the chain businesses that have gas stations integrated into their sites. Several big box stores and large grocery stores have expanded their presence in the retail

48 State of California, Governor's Office of Business and Economic Development. November 2015. *Hydrogen Station Permitting Guidebook: Best practices for planning, permitting and opening a hydrogen fueling station.* www.business.ca.gov/Programs/Permits/HydrogenStationPermitting.aspx.

49 National Association of Convenience Stores. *2015 NACS Retail Fuels Report.* p. 29. http://www.nacsonline.com/YourBusiness/FuelsReports/2015/Documents/2015-NACS-Fuels-Report_full.pdf.

fueling market over the last decade. Partnering with such a business that has multiple locations in California could provide a mutually beneficial relationship in which the hydrogen station developer could work with one entity to have consistent lease agreements and perhaps even station design (if the chain uses consistent design across its locations), and the chain store could have a means for providing community benefits and mitigating environmental impacts.

Big box/grocery retailers that have the greatest number of gas stations in the United States are Kroger (represented in California by Ralphs, Food4Less, Quik Stop Market, and Foods Co.), Walmart (but none of its Murphy USA sites are in California), Sam's Club, Costco, and Safeway.[50] One caveat is that hydrogen station developers should be aware that some jurisdictions in California have what are commonly referred to as "big box ordinances,"[51] some of which add layers of discretionary planning review to these projects. Developers should confirm with AHJs whether additional land-use entitlements would be triggered by adding a hydrogen station component to such a site before committing to such a partnership.

50 Ibid., p. 30.

51 Background information on big box relations: California Planning & Development Report, http://www.cp-dr.com/articles/node-638.

APPENDIX F: Financial Assessment of Four Station Types

The following financial assessments, or "scorecards," as of September 30, 2016, are output from the Hydrogen Financial Analysis Scenario Tool (H2FAST) for hydrogen refueling stations.[52] The H2FAST model was used to describe four of the various refueling station types and architectures funded by the ARFVTP: 180 kg per day delivered gaseous, 350 kg per day delivered liquid, 130 kg per day electrolysis, and a second 180 kg per day delivered gaseous. The scorecards include station capital equipment costs, station O&M costs, upfront financing by source, key financial parameters, financial performance, and value contributions in terms of invested dollar per kg of hydrogen.

The assessments are based on input from conversations with station developers, Energy Commission grant agreement files, invoices, and the station developers' input to the NREL Data Collection Tool, which is required for payment of eligible expenses. The Energy Commission works in collaboration with the NREL National Fuel Cell and Technology Evaluation Center to collect, quantify, and analyze hydrogen station throughput data and O&M costs.[53] In some cases, station developers pay for maintenance themselves, and this includes direct labor and parts, when the amount of O&M funding exceeds O&M costs.

The four station designs evaluated here are only some of the possible design approaches. Opportunities also exist for performance upgrades for these stations types and others. Since this industry remains at an early stage, many different station architectures are possible, and these may yield new funding impacts. The Energy Commission staff participates in H2USA and will continue to evaluate hydrogen refueling station costs with the Working Groups' assessment of the Reference Station Design Task.[54]

The results for each station are indicated in these scorecards sections:

- Upfront financing estimate by source
- Key financial parameters
- Key assumptions
- Financial performance at break-even retail price
- Real levelized value contributions ($/kg H_2)

52 National Renewable Energy Laboratory. Hydrogen Financial Analysis Scenario Tool (H2FAST). http://www.nrel.gov/hydrogen/h2fast/.

53 National Renewable Energy Laboratory. Fuel Cell and Hydrogen Technology Validation. www.nrel.gov/hydrogen/proj_tech_validation.html.

54 Pratt, Joseph, Danny Terlip, Chris Ainscough, Jennifer Kurtz, and Amgad Elgowainy. 2015. *H2FIRST Reference Station Design Task, Project Deliverable 2-2*. National Renewable Energy Laboratory and Sandia National Laboratories. http://www.osti.gov/scitech/servlets/purl/1215215.

A few important metrics shown on these scorecards are the break-even price of hydrogen, the revenue price of hydrogen, the profitability index (PI), and the project net present value (NPV).[55] The revenue price of hydrogen, given as $9.74 in each scorecard, is an estimated competitive price floor, which production pathway models indicate to be an achievable price in a competitive market. The NPV compares the amount invested today to the present value of the future cash receipts from the investment. This PI is calculated as the present value of future cash flows and initial investment.

If the PI is greater than 1, then the project is expected to have a higher amount of cash flows than the initial investment. In the following, most have a PI greater than 1. Another metric is cash outflow, which is based on hydrogen sold per kg. Most cash outflows are operating expenses, for example, cost of delivered hydrogen, equipment, electricity, rent, maintenance, and property insurance. In the following, the cash outflows vary due to variations in operating expenses, such as electricity and rent. Rent can vary as much as $4,000 to$6,000 per month.

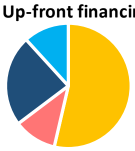
55 McKinney, Jim, et al. 2015. *Joint Agency Staff Report on Assembly Bill 8: Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California.* California Energy Commission. Publication Number: CEC-600-2015-016. p. 68. http://www.energy.ca.gov/2015publications/CEC-600-2015-016/CEC-600-2015-016.pdf.

Figure F-1 shows the scorecard for a 180 kg/day delivered gaseous station installed with $1,451,000 in capital expenditure grants and station developers' match funds, with a total capital cost of $2,406,000 along with $300,000 in O&M funding. The results show a break-even hydrogen price would be $9.46 per kg, while the retail price of hydrogen is $9.74 per kg. The profitability index (PI), which is the ratio of payoff to investment of a proposed project, is 1.65. Since the PI is greater than one, the project has a potential to make a profit assuming equipment life of 20 years, one of the key assumptions. The details are covered in Table F-2.

Figure F-1: Scorecard for a 180 kg/day, Gaseous Delivery Station – System 1

Delivered Gaseous Hydrogen-System 1

Up-front financing estimate by source

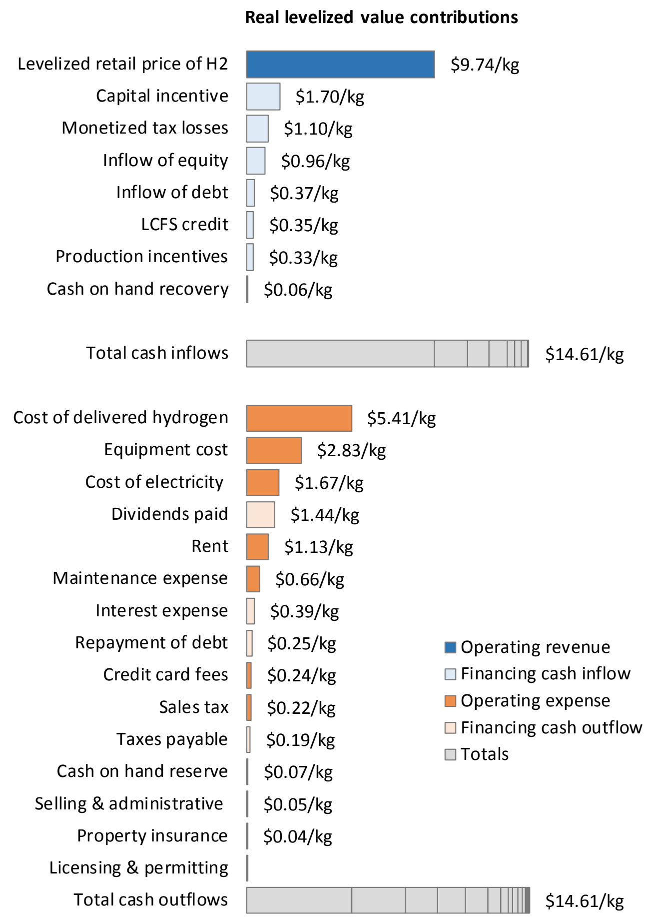


CEC funding	$	1,451,000
Equity (estimate)	$	637,000
Debt (estimate)	$	318,000
Total capital cost	**$**	**2,406,000**
CEC O&M support	$	300,000
Private financing / CEC financing ($/$)		0.22

Key financial parameters		
First year retail price of H2 ($/kg)	$	15.21
Levelized retail price of H2 ($/kg)	$	9.74
First year cost of delivered H2 ($/kg)	$	8.62
Levelized cost of delivered H2 ($/kg)	$	5.41
Levelized cost of electricity ($/kWh)	$	0.177
Electricity use (kWh/kg)		9.41
First year maintenance ($/year)	$	28,777

Key assumptions	
Nameplate capacity (kg/day)	180
Project initiation year	2016
Equipment operational life (years)	20
Long term equipment utilization	80%
Demand ramp-up period (years)	7.0

Financial performance at break-even retail price		
Levelized break-even price of hydrogen ($/kg)	$	9.46
Levelized retail margin ($/kg)	$	4.32
Levelized break-even margin ($/kg)	$	4.05
Project NPV		$148,000
Profitability index		1.65



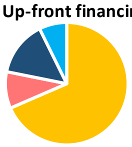
Source: NREL

Figure F-2 shows the scorecard for a 350 kg/day delivered liquid station installed with \$2,125,000 in capital expenditure grants and station developers' match funds, with a total capital cost of \$2,803,000 along with \$300,000 in O&M funding. The results show a break-even hydrogen price would be \$7.85 per kg, while the retail price of hydrogen is \$9.74 per kg. The electricity price and use in this scorecard are the same as in the Figure F-1 scorecard, since the electricity data specific to System 2 are not available at this time. The PI is 5.19, assuming equipment life of 20 years. Details are covered in Table F-4.

Figure F-2: Scorecard for a 350 kg/day, Liquid Delivery Station – System 2

Delivered Liquid Hydrogen-System 2

Up-front financing estimate by source



CEC funding	$	2,125,000
Equity (estimate)	$	452,000
Debt (estimate)	$	226,000
Total capital cost	**$**	**2,803,000**
CEC O&M support	$	300,000
Private financing / CEC financing ($/$)		0.11

Key financial parameters

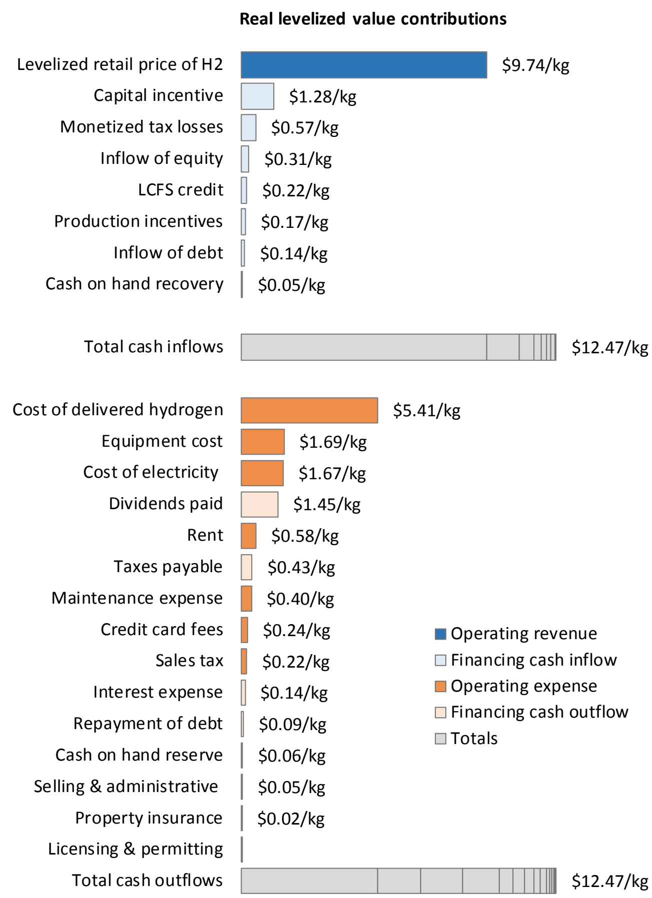
First year retail price of H2 ($/kg)	$	15.21
Levelized retail price of H2 ($/kg)	$	9.74
First year cost of delivered H2 ($/kg)	$	8.62
Levelized cost of delivered H2 ($/kg)	$	5.41
Levelized cost of electricity ($/kWh)	$	0.177
Electricity use (kWh/kg)		9.41
First year maintenance ($/year)	$	33,526

Key assumptions

Nameplate capacity (kg/day)	350
Project initiation year	2016
Equipment operational life (years)	20
Long term equipment utilization	80%
Demand ramp-up period (years)	7.0

Financial performance at break-even retail price

Levelized break-even price of hydrogen ($/kg)	$	7.85
Levelized retail margin ($/kg)	$	4.32
Levelized break-even margin ($/kg)	$	2.44
Project NPV		$875,000
Profitability index		5.19



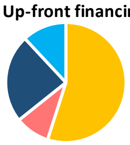
Source: NREL

Figure F-3 shows the scorecard for a 130 kg/day electrolysis station installed with $1,769,000 in capital expenditure grants and station developers' match funds, with a total capital cost of $2,920,000 along with $300,000 in O&M funding. The results show that a break-even hydrogen price would be $19.78 per kg, while the retail price of hydrogen is $9.74 per kg. The higher break-even price is due to a much higher cost of electricity. Since the PI is below one, additional investment is needed to make the project profitable, assuming equipment life of 20 years. Details are covered in Table F-6.

Figure F-3: Scorecard for a 130 kg/day, Electrolysis Station – System 3

On-Site Electrolysis-System 3

Up-front financing estimate by source

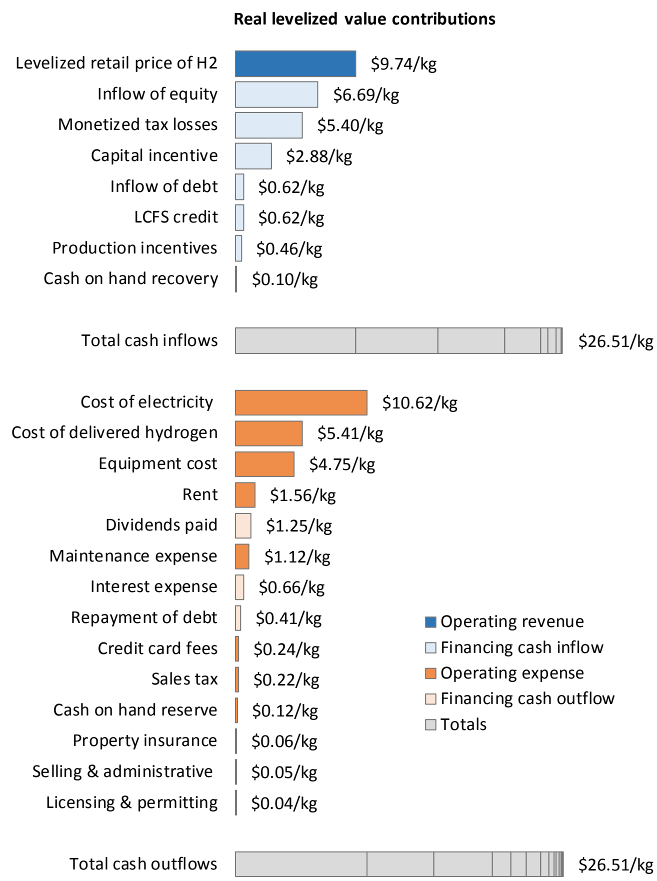


CEC funding	$	1,769,000
Equity (estimate)	$	767,000
Debt (estimate)	$	384,000
Total capital cost	**$**	**2,920,000**
CEC O&M support	$	300,000
Private financing / CEC financing ($/$)		0.22

Key financial parameters		
First year retail price of H2 ($/kg)	$	15.21
Levelized retail price of H2 ($/kg)	$	9.74
First year cost of delivered H2 ($/kg)	$	8.62
Levelized cost of delivered H2 ($/kg)	$	5.41
Levelized cost of electricity ($/kWh)	$	0.177
Electricity use (kWh/kg)		60.00
First year maintenance ($/year)	$	34,925

Key assumptions	
Nameplate capacity (kg/day)	130
Project initiation year	2016
Equipment operational life (years)	20
Long term equipment utilization	80%
Demand ramp-up period (years)	7.0

Financial performance at break-even retail price		
Levelized break-even price of hydrogen ($/kg)	$	19.78
Levelized retail margin ($/kg)	$	4.32
Levelized break-even margin ($/kg)	$	14.37
Project NPV		-$1,296,000
Profitability index		(3.36)



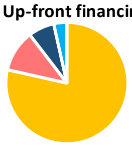
Source: NREL

Figure F-4 shows the scorecard for a 180 kg/day delivered gas station installed with $2,125,000 in capital expenditure grants and station developers' match funds, with a total capital cost of $2,406,000 along with $300,000 in O&M funding. The results show that a break-even hydrogen price at $6.54 per kg, while the retail price of hydrogen is $9.74 per kg. The PI is 7.17, indicating the project can be profitable, assuming equipment life of 20 years. Details are covered in Table F-8.

Figure F-4: Scorecard for a 180 kg/day, Gaseous Delivery Station – System 4

Delivered Gaseous Hydrogen-System 4

Up-front financing estimate by source



CEC funding	$	2,125,000
Equity (estimate)	$	187,000
Debt (estimate)	$	94,000
Total capital cost	**$**	**2,406,000**
CEC O&M support	$	300,000
Private financing / CEC financing ($/$)		0.04

Key financial parameters

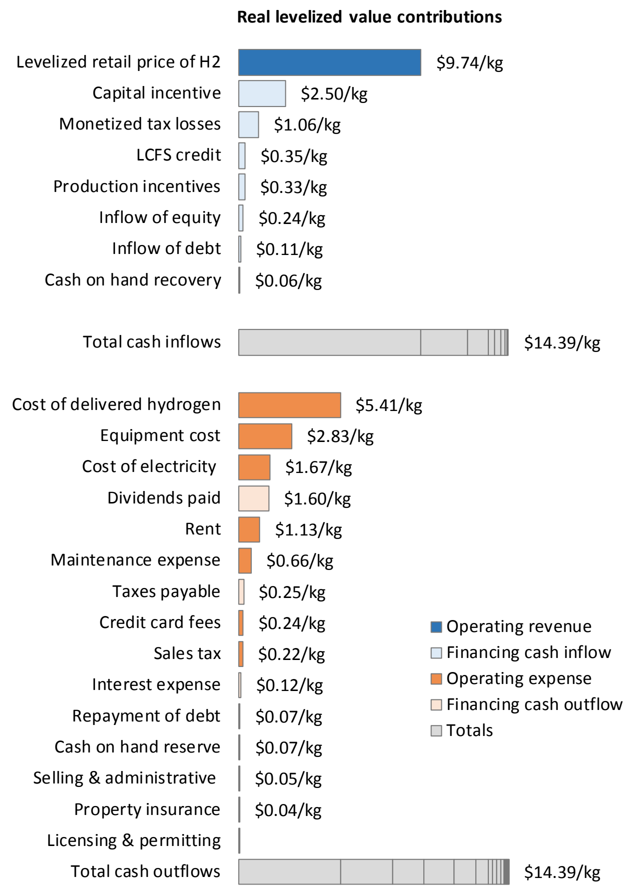
First year retail price of H2 ($/kg)	$	15.21
Levelized retail price of H2 ($/kg)	$	9.74
First year cost of delivered H2 ($/kg)	$	8.62
Levelized cost of delivered H2 ($/kg)	$	5.41
Levelized cost of electricity ($/kWh)	$	0.177
Electricity use (kWh/kg)		9.41
First year maintenance ($/year)	$	28,777

Key assumptions

Nameplate capacity (kg/day)	180
Project initiation year	2016
Equipment operational life (years)	20
Long term equipment utilization	80%
Demand ramp-up period (years)	7.0

Financial performance at break-even retail price

Levelized break-even price of hydrogen ($/kg)	$	6.54
Levelized retail margin ($/kg)	$	4.32
Levelized break-even margin ($/kg)	$	1.12
Project NPV		$698,000
Profitability index		7.17



Source: NREL

Delivered Gaseous Hydrogen – System 1

This system uses delivered gas and has daily fueling capacity of 180 kg. The gas is produced using steam methane reformation (SMR) – a method used for producing hydrogen from a methane source, such as natural gas, using high-temperature steam– and is transported to refueling stations using a tube trailer (250 kg capacity). The round trip, spanning major metropolitan areas and beyond, averages 95 miles. Table F-1 lists the station equipment costs, and Table F-2 integrates those costs with engineering, permitting, construction, and general management and overhead. The numbers in these tables reflect both the grant funding and match funding. The costs in Table F-2 are updated from what was published in the 2015 Joint Report.

Table F-1: Equipment Cost for 180 kg/day Delivered Gaseous Hydrogen System 1

FirstElement Fuel Hydrogen Refueling Station Developed Under ARFVTP Grant		
Equipment List	**Delivered Cost ($)**	**Notes and Specifications**
Ground Storage	$ 370,000	250 kg Type 3 - 25 tubes
Compressor	$ 270,000	40 HP reciprocating compressor
Dispenser	$ 270,000	Dual-hose, H35 and H70
High-Pressure Tubes	$ 135,000	Fiba™ Type 2 storage tubes - 3 @ $45,000 each
Refrigerator and Cooling Block	$ 150,000	Aluminum block with internal coil tubing
Tubing and Valves	$ 150,000	Specialty tubing and valves for high pressure hydrogen systems
Misc. Material and Equipment	$ 230,000	Electrical- and construction-related materials
Point-of-Sale System	$ 20,000	N/A
Utility Connection Equipment	$ 12,000	N/A
Total Equipment and Material	**$ 1,607,000**	

Source: California Energy Commission staff. Printed with permission from station developer.

Table F-2: Engineering, Construction, and General Overhead Costs for System 1

FirstElement Fuel Hydrogen Refueling Station Developed Under ARFVTP Grant	
Activity	**Cost ($)**
Site Engineering and Design	$ 55,800
Permitting	$ 42,400
Construction	$ 624,000
Commissioning	$ 35,700
Project Management and General Overhead	$ 41,100
Activity Subtotal	$ 799,000
Total Equipment	$ 1,607,000
Total Installed Cost	**$ 2,406,000**

Source: California Energy Commission staff. Printed with permission from station developer.

Delivered Liquid Hydrogen – System 2

As of September 30, 2016, California's two open retail stations that use delivered liquid hydrogen each have a nameplate capacity of 350 kg/day. A central facility produces the liquid hydrogen using SMR and converts the gas to liquid. The liquid hydrogen is transported to the refueling stations using a delivery trailer and stored at the stations. The round-trip delivery (4,000 kg) averages 467 miles. Table F-3 lists the station equipment costs, and Table F-4 integrates those costs with engineering, permitting, construction, and general management and overhead. The numbers in these tables reflect both the grant funding and match funding. The costs published in the 2015 Joint Report are the same.

Table F-3: Equipment Costs for a 350 kg/day Delivered Liquid Hydrogen System 2

Linde Hydrogen Refueling Station Developed Under ARFVTP Grant		
Equipment List	**Delivered Cost ($)**	**Notes and Specifications**
Liquid Storage	$ 1,314,000	Refurbishment of 1 vessel, 3000 gallons
High-Pressure Tubes		
Compressors		Linde IC90, ionic compression unit and cold fill
		High pressure liquid pump and evaporator
Dispenser		H35/H70 Bar Dispenser & Chiller
Point-of-Sale System		
Connection to Utilities	$ 42,000	
Misc. Material and Equipment	$ 574,000	Electrical and construction-related materials
Total Equipment and Material	**$ 1,930,000**	

Source: California Energy Commission staff. Printed with permission from station developer.

Table F-4: Engineering, Construction, and General Overhead Costs for System 2

Linde Hydrogen Refueling Station Developed Under ARFVTP Grant	
Activity	**Cost ($)**
Site Engineering and Design	$ 50,000
Permitting	$ 31,000
Construction	$ 599,000
Commissioning	$ 76,000
Project Management and General Overhead	$ 117,000
Activity Subtotal	$ 873,000
Equipment	$ 1,930,000
Total Installed Cost	**$ 2,803,000**

Source: California Energy Commission staff. Printed with permission from station developer.

On-Site Electrolysis – System 3

As of September 30, 2016, California has three operational and six planned on-site electrolysis hydrogen refueling stations, which can dispense between 100 and 140 kg/day, depending on configuration. Electrolysis involves a process of passing an electrical current through water to produce hydrogen gas. The gas collection, compression, and storage are done at the station.

Table F-5 shows the station equipment costs for an electrolysis station. Although there is no need for delivered fuel, it is possible for the station to dispense hydrogen from a combination of delivered gas and on-site electrolysis. Table F-6 integrates equipment costs with engineering, permitting, construction, and general management and overhead. The numbers in these tables reflect both the grant funding and match funding. The total equipment and material are nearly $300,000 less than published in the 2015 Joint Report.

Table F-5: Equipment Cost for 130 kg/day Hydrogen System 3

HyGen Hydrogen Refueling Station – Orange (planned to be developed under ARFVTP grant)		
Equipment List	**Delivered Cost ($)**	**Notes and Specifications**
Ground Storage	$ 222,000	84.6 kg at 450 Bar - 12 tubes (7 kg/tube)
High-Pressure Tubes	$ 53,000	14 kg at 1,000 Bar - 2 tubes (7 kg/tube)
Electrolyzer	$ 1,008,000	15 Bar
Compressors	$ 147,000	For H35
	$ 123,000	H70 Bar booster
Dispenser	$ 392,000	H35/H70 Bar Dispenser & Chiller, includes Point-of-Sale
Chiller	$ 19,000	Pre-Chiller for High Pressure
Misc. Material and Equipment	$ 128,000	Electrical and construction-related materials
Total Equipment and Material	**$ 2,092,000**	

Source: California Energy Commission staff. Printed with permission from station developer.

Table F-6: Engineering and Construction Costs for System 3

HyGen Hydrogen Refueling Station – Orange (planned to be developed under ARFVTP grant)	
Activity	**Cost [$]**
Site Engineering and Design	$ 50,000
Permitting	$ 52,000
Construction	$ 370,000
Commissioning	$ 133,000
Project Management	$ 223,000
Activities Subtotal	$ 828,000
Equipment	$ 2,092,000
Total Installed Cost	**$ 2,920,000**

Note: HyGen's total cost does not include General Overhead.

Source: California Energy Commission staff. Printed with permission from station developer.

Delivered Gaseous Hydrogen – System 4

California plans two 180 kg/day stations that cascade gaseous (delivered) hydrogen into high-pressure storage. The gaseous hydrogen then passes through the heat exchanger and into the H35 and H70 dispensers. Table F-7 shows the station equipment costs, and Table F-8 integrates site engineering and design, permitting, construction, commissioning, and project management. The numbers in these tables reflect both the grant funding and match funding. The costs for this station were not published in the 2015 Joint Report, and this station is the first from this developer in California.

Table F-7: Equipment Cost for 180 kg/day Delivered Gaseous Hydrogen–System 4

Air Liquide Hydrogen Refueling Station Planned to be Developed Under ARFVTP Grant		
Equipment List	**Delivered Cost ($)**	**Notes and Specifications**
Ground Storage	$ 162,426	
Compressor	$ 500,000	Integration in classified skid and manufacturing project and FAT
Dispenser	$ 97,680	
High-Pressure Tubes	$ 237,000	
Chiller	$ 230,000	H2 Cooler/Cooling Block/Cooling Water Unit
Tubing and Valves	$ 48,635	
Misc. Material and Equipment	$ 20,000	
Point-of-Sale System	$ 56,405	
Utility Connection Equipment	$ 200,000	Piping for Hydraulic Aggregate/Cooling Fluid Unit; Electrical Integration in nonclassified skid (cabling/wiring, junction boxes, electrical and power cabinets)
Total Equipment and Material	**$ 1,552,146**	

Source: California Energy Commission staff. Printed with permission from station developer.

Table F-8: Engineering, Construction, and General Overhead Costs for System 4

Air Liquide Hydrogen Refueling Station Planned to be Developed Under ARFVTP Grant	
Activity	**Cost ($)**
Site Engineering and Design	$ 161,333
Permitting	$ 5,684
Construction (Includes Project Management)	$ 507,312
Commissioning	$ 28,751
Project Management and General Overhead	$ 100,000
Activities Subtotal	$ 853,080
Total Equipment	$ 1,552,146
Total Installed Cost	**$ 2,405,226**

Source: California Energy Commission staff. Printed with permission from station developer.

Table F-9 shows the breakdown of station equipment costs, and Table F-10 shows other major cost elements of the four systems side by side. Table F-10 shows total installed cost ranges from $2.4 million to $3.2 million. As station use increases, the fixed costs will eventually be distributed into a larger quantity of kilograms of hydrogen sold, diminishing as a per-kilogram expense. For example, once demand increases to ~50 percent (roughly five times larger than today), the cost contribution of such fixed expenses would be 1/5 or 20 percent of the contribution today.

This report maintains the 2015 Joint Report findings that capital expenditure costs could decrease up to 50 percent between 2017 and 2025 because hydrogen station equipment costs should decline as equipment packages are standardized, larger stations are developed, equipment is produced at higher volumes, and station developers learn and apply more efficient integration and installation techniques.[56]

Table F-9: Comparison of the Major Cost Elements for Four Station Types

Equipment				
Equipment List	Delivered Cost ($)			
	System 1	System 2	System 3	System 4
Ground Storage (gaseous or liquid)	$ 370,000		$ 222,000	$ 162,426
High-Pressure Tubes	$ 135,000		$ 53,000	$ 237,000
Electrolyzer			$ 1,008,000	
Compressors	$ 270,000	$ 1,314,000	$ 147,000	$ 500,000
			$ 123,000	
Chiller	$ 150,000		$ 19,000	$ 230,000
Dispenser	$ 270,000		$ 392,000	$ 97,680
Point-of-Sale System	$ 20,000			$ 56,405
Connection to Utilities	$ 12,000	$ 42,000	$ 15,000	$ 200,000
Tubing and Valves	$ 150,000	$ 574,000		$ 48,635
Misc. Material and Equipment	$ 230,000		$ 113,000	$ 20,000
Total Equipment and Material	**$ 1,607,000**	**$ 1,930,000**	**$ 2,092,000**	**$ 1,552,146**

Source: California Energy Commission staff. Printed with permission from station developers.

56 McKinney, Jim, et al. 2015. *Joint Agency Staff Report on Assembly Bill 8: Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California.* California Energy Commission. Publication Number: CEC-600-2015-016. pp. 4-5, 51, 93. http://www.energy.ca.gov/2015publications/CEC-600-2015-016/CEC-600-2015-016.pdf.

Table F-10: Engineering, Construction, and General Overhead Costs for Four Station Types

Estimated Total Hydrogen Station Costs for Four Systems				
Activity	Cost [$]			
	System 1	System 2	System 3	System 4
Site Engineering and Design	$ 55,800	$ 50,000	$ 50,000	$ 161,333
Permitting	$ 42,400	$ 31,000	$ 52,000	$ 55,684
Construction	$ 624,000	$ 599,000	$ 370,000	$ 507,312
Commissioning	$ 35,700	$ 76,000	$ 133,000	$ 28,751
Project Management and General Overhead*	$ 41,100	$ 117,000	$ 223,000	$ 100,000
Activity Subtotal	$ 799,000	$ 873,000	$ 828,000	$ 853,080
Total Equipment	$ 1,607,000	$ 1,930,000	$ 2,092,000	$ 1,552,146
Total Installed Cost	**$ 2,406,000**	**$ 2,803,000**	**$ 3,212,000**	**$ 2,405,226**

Source: California Energy Commission staff. Printed with permission from station developers.

System Power

The station scorecards in Figures F-1 through F-4 show system power as an O&M cost. Some ARFVTP-funded stations are experiencing higher than expected costs for electricity used for system power. For example, some report costs as high as 50¢/kWh. Upon closer examination, the majority of the station blended cost of electricity stems from fixed charges and demand charges. This is a natural outcome of currently low utilization levels of the infrastructure. System power along with Internet service provider costs and station security costs are eligible expenses for Energy Commission O&M grants.

Fueling events during peak demand hours often trigger immediate compressor activation; hydrogen refueling stations turn on compressors to recover cascade hydrogen storage to prepare for back-to-back refueling of FCEVs. In doing so, electricity demand charges are incurred ($/kW), usually in peak demand electric rate structures, thus incurring the maximum monthly demand expense. In this way, monthly electricity demand charges become a fixed cost for any operating station.

Stations are also seeing high energy charges. Again, this is because most energy would be consumed in peak electric hours. Another source of fixed electricity charges stems from the precooling systems in the hydrogen refueling station. To be ready for fast refueling, the chiller stays on 24/7, thus incurring a fixed energy consumption to just stay cold. This energy consumption is in fact a fixed cost for electricity as well.

Senate Bill 350 (De León, Chapter 547, Statues of 2015) requires the amount of electricity generated and sold to retail customers per year from eligible renewable energy sources be increased from 33 percent by December 31, 2020, to 50 percent by December 31, 2030. The bill also encourages investment in transportation electrification to meet air quality and climate change goals but recognizes that increased electricity demand from the transportation sector could affect the ability of utility companies to meet the renewable targets. The bill also tasks the Energy Commission, ARB, the California Public Utilities Commission, utilities, and other stakeholders to work together to plan for transportation electrification in the context of SB 350.

Station developers, as consumers of renewable electricity (for both station power and as a source of renewable hydrogen), should also recognize that SB 350 is prompting new analyses on how these renewable goals will be met and how the cost of electricity could be affected.

Safety Planning

GFO-15-605 requires a "safety plan" which the U.S. DOE Hydrogen Safety Panel evaluates according to the U.S. DOE Hydrogen Safety Panel's *Safety Planning for Hydrogen and Fuel Cell Projects*, dated March 2016.[57] The cost to a station developer for writing the plan varies from developer to developer but is estimated at $10,000 to $20,000.

Hydrogen Purity Testing

Before declaring a station operational, station developers arrange a hydrogen purity test according to CCR, Title 4, Division 9, Chapter 6, Sections 4180 and 4181, which adopts SAE International J2719. The estimated cost per evaluation is $2,500 to $5,000, and the process typically takes one to two weeks.

The typical purity test report details the particulate filter, which screens for particles to 0.2 micrometer, and provides particulate concentration data relative to the amount of hydrogen tested in kilograms. The report provides analytical data for nonhydrogen gaseous constituents, consisting of 13 impurity constituents including water, total hydrocarbons, oxygen, helium, nitrogen, argon, carbon dioxide, carbon monoxide, and sulfur. In addition to these impurities, nonmethane hydrocarbons – those species other than methane that contain hydrogen, carbon, and potentially oxygen (hydrogen for fuel is especially tested for the specific hydrocarbon formaldehyde, CH_2O) – are tested for concentration. The analytical data used to determine the concentrations are also included.

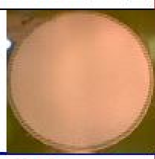
The report includes the maximum concentration of each impurity constituent, detection limits for the test laboratory, and the test method used. The hydrogen fuel index, describing the overall purity, is also reported. An example of a fuel quality report template is shown in Figure F-5. The constituents tested are listed down the left column. The next columns show the SAE J2719 allowed limits and the detection limits of the testing company's equipment. The rightmost column is where the test results would be listed for the tested station. Since Figure F-5 is just a template, this column is blank. Figure F-5 is the summary sheet for one testing company, but many companies exist that can conduct purity testing.

57 · Pacific Northwest National Laboratory. *Safety Planning for Hydrogen and Fuel Cell Projects*. March 2016. https://h2tools.org/sites/default/files/Safety_Planning_for_Hydrogen_and_Fuel_Cell_Projects-March_2016.pdf.

Figure F-5: Sample Fuel Quality Report Template

SmartChemistry

CALIFORNIA HYDROGEN STATION

SAE J2719 Constituents	SAE J2719 Limits - µmol/mol	Smart Chemistry Detection Limits - µmol/mol	H70 H2 @Nozzle sampled on Date, Time Concentration (µmol/mol)
H_2O	5	0.5	
Total Hydrocarbons (C, Basis)	2		
Methane		0.001	
Acetone		0.001	
O_2	5	1	
He	300	10	
N_2 & Ar	100		
N_2		2	
Ar		0.4	
CO_2	2	0.1	
CO	0.2	0.0005	
Total S	0.004		
Hydrogen Sulfide		0.000002	
Carbonyl Sulfide		0.000002	
Methyl Mercaptan (MTM)		0.00001	
Ethyl Mercaptan (ETM)		0.00001	
Dimethyl Sulfide (DMS)		0.00001	
Carbon Disulfide		0.000002	
Isopropyl Mercaptan (IPM)		0.00001	
Tert-Butyl Mercaptan (TBM)		0.00001	
n-Propyl Mercaptan		0.00001	
n-Butyl Mercaptan		0.00001	
Dimethyl Disulfide (DMDS)		0.00001	
Tetrahydrothiophene (THT)		0.00001	
Formaldehyde	0.01	0.001	
Formic Acid	0.2	0.001	
Ammonia	0.1	0.01	
Total Halogenates	0.05		
Cl_2		0.0004	
HCl		0.0001	
HBr		0.0002	
Total Organic Halides (32 compounds in red and bold listed in "Non-Methane Hydrocarbons")		0.001 (Smart Chemistry limit is for each individual organic halide compound)	
Tetrachloro-hexafluorobutanes			
Particulate Concentration	1 mg/kg		
Particulates Found & Size 			
Hydrogen Fuel Index			

Source: Smart Chemistry Corporation

APPENDIX G: Incentives and Funding

In addition to the AB 8 funding for hydrogen refueling stations, other governmental programs and incentives contribute to the development of hydrogen refueling stations in California. Some regional air districts provide grant funding for hydrogen refueling stations, often to further leverage the investment of ARFVTP dollars awarded to stations within their jurisdictions. Other types of support provided by the State include loans and tax exemptions or exclusions. This appendix summarizes some of these incentives that station developers may pursue to reduce station costs.

Regional Grant Funding

Bay Area Air Quality Management District

In Fiscal Year Ending (FYE) 2016, the BAAQMD opened a solicitation to help accelerate the deployment of hydrogen refueling stations in the BAAQMD's jurisdiction. The BAAQMD offered up to $500,000, with funding limited to 25 percent of the total project cost and not to exceed a maximum award amount of $250,000 per station, to hydrogen refueling stations projects that had received a passing score and/or received approval for funding from a State or Federal agency. Given that this funding cycle did not coincide with a State or Federal grant solicitation, the BAAQMD did not receive any applications.

In FYE 2017 (July 1, 2016 – June 30, 2017), the BAAQMD again plans to open a solicitation for hydrogen refueling stations, with more detailed information forthcoming. The hydrogen refueling station support is made possible through BAAQMD's Transportation Fund for Clean Air (TFCA) Regional Fund. Potential applicants are encouraged to monitor the TFCA program website and sign up to receive TFCA email alerts.[58]

A BAAQMD solicitation for hydrogen refueling station closed in March 2015. In this solicitation, the BAAQMD awarded more than $2.2 million to three companies for the accelerated installation of 12 hydrogen refueling station projects, also funded by the Energy Commission, in the San Francisco Bay Area.

South Coast Air Quality Management District

The SCAQMD identifies "Hydrogen and Fuel Cell Technologies and Infrastructure" as one of the core technologies of focus for its Clean Fuels Program. In calendar year 2015, this program funded $10.7 million in executed contracts, of which 12 percent went to the hydrogen technology area. The agency has invested $13.4 million in hydrogen refueling stations to date

58 The BAAQMD's TFCA Regional Fund website is http://www.baaqmd.gov/grant-funding/public-agencies/regional-fund. Sign up for email alerts at https://www.surveymonkey.com/r/?sm=%2bvf6nYZFH0Lb%2fkFZpA84aQ%3d%3d.

through the program. This amount includes $3.2 million in supplemental capital and operating expense support between 2010 and 2015 for the modern network of public hydrogen refueling stations in Southern California. These grants average about $150,000 per station and range from $100,000 to $330,000. In calendar year 2016, SCAQMD plans to contribute $1.5 million toward the continued development of hydrogen technology in Southern California and $350,000 to develop business case strategies for securing long-term funding to complete hydrogen refueling station build-out.[59] These strategies include analyzing renewable hydrogen and evaluating liquid hydrogen setback requirements.

Tax Programs

The State offers several tax incentives that may apply to aspects of hydrogen refueling station projects. A few of these incentives are discussed below, along with brief descriptions of program rules. Due to the complexity of tax law, however, station developers should always seek advice from the responsible State agency before claiming a tax exemption and not assume that just because a tax incentive is listed below that it means that a station developer will qualify for it. Getting advice in writing is the best way to protect oneself from misinterpretation of the law. In a case where a station developer does not know/plan for sales tax, the penalty could compound quickly and could go to the collection unit of the California Board of Equalization (BOE). Any payments made would first go to the principal, then to the interest owed, and finally to the penalty after each is paid off.

Tax Exclusion for Alternative Energy Source and Advanced Transportation Technology Projects

Senate Bill 71 (Padilla, Chapter 10, Statutes of 2010) created, and Senate Bill 1128 (Padilla, Chapter 677, Statutes of 2012) amended a sales and use tax exclusion (STE) program for companies involved in alternative energy source, advanced transportation technology, and advanced manufacturing projects in California. The California Alternative Energy and Advanced Transportation Financing Authority (CAEATFA) administers the program along with other programs, such as a tax-exempt bond financing program for green projects.

Interest in this program has grown substantially in the last year. At the same time, the Legislature has expanded the types of eligible projects, meaning competition for these tax exclusion grants should remain high. The STEs awarded by CAEATFA are capped at $100 million per calendar year. After five calendar years in which the program grants did not reach the cap amount,[60] the program was oversubscribed in 2015. Application requests that were eligible for consideration at the December 2015 CAEATFA board meeting exceeded the year's

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59 South Coast Air Quality Management District, Technology Advancement Office, *Clean Fuels Program 2015 Annual Report and 2016 Plan Update.* March 2016. http://www.aqmd.gov/docs/default-source/technology-research/annual-reports-and-plan-updates/2015annualreport_2016planupdate.pdf?sfvrsn=6.

60 California Alternative Energy and Advanced Transportation Financing Authority. *Sales and Use Tax Exclusion Program Report to the California State Legislature.* December 2014. p. 10. http://www.treasurer.ca.gov/caeatfa/ste/report.pdf.

cap by $74 million, and additional applications had already been received that would have exhausted the 2016 funding.[61]

In response to the growth in program demand, CAEATFA temporarily suspended the program in November 2015 to allow time for additional program regulations to be adopted. On July 22, 2016, CAEATFA issued a Notice of Emergency Regulations to incorporate recycled feedstock projects into the program, a new requirement under Assembly Bill 199 (Eggman, Chapter 768, Statutes of 2015), and to add details about the application submission and evaluation processes. New details include limiting the per-project STE to $20 million per calendar year and creating a secondary process for requesting additional funds over the $20 million if there are remaining program funds at the end of the year. To help administer the limited funds in a more effective and equitable way, CAEATFA also defined competitive criteria by which applications will be ranked and awarded once the program is oversubscribed.[62] These proposed modifications were approved by the Office of Administrative Law on August 9, 2016,[63] and the program is again accepting applications on a rolling basis. Applications are considered at the first board meeting at least 60 days after the completed application was submitted.[64] This program is authorized through January 1, 2021 (Assembly Bill 1269, Dababneh, Chapter 788, Statutes of 2015).

Partial Sales and Use Tax Exemption for Manufacturing and Research and Development Equipment

Beginning on July 1, 2014, and continuing until June 30, 2022, a partial sales and use tax exemption is in effect for certain manufacturing and research and development equipment purchases and leases.[65]

This exemption is described in Sales and Use Tax Law, Chapter 4, Section 6377.1. The partial exemption rate is 4.1875 percent, meaning that a qualified purchase would be taxed at a rate of 3.3125 percent (the 7.50 percent statewide tax rate – 4.1875), plus any applicable local, city, county, or district tax. Eligibility for this partial exemption is determined by if the purchaser is:

- A qualified person, meaning a person primarily engaged in one of the types of business specified (more details below).
- Purchasing qualified property, meaning tangible personal property like machinery or equipment.

61 California Alternative Energy and Advanced Transportation Financing Authority. Staff Report. *Request to Suspend the Acceptance and Consideration of New Applications Under the Sales and Use Tax Exclusion Program.* November 2015. http://www.treasurer.ca.gov/caeatfa/staff/2015/20151117/4b.pdf.

62 CAEATFA Modified Text of Regulations. 2016. http://www.treasurer.ca.gov/caeatfa/ste/regulations/20160810.pdf.

63 California State Treasurer. CAEATFA STE Regulations. http://www.treasurer.ca.gov/caeatfa/ste/regulations/index.asp.

64 California State Treasurer. CAEATFA STE Application Materials. http://www.treasurer.ca.gov/caeatfa/ste/application/index.asp.

65 California State Board of Equalization. Manufacturing and Research & Development Exemption. http://www.boe.ca.gov/sutax/manufacturing_exemptions.htm#page=Overview.

- Using the qualified property for a qualified use, such as in any stage of manufacturing, in research and development, for maintenance or repair of qualified property, or for use by a contractor working on behalf of a qualified person for a qualified use.

BOE encourages individuals/companies to ask it for advice in writing regarding sales and use taxes. The BOE's publication for how to submit questions is found at this web address: http://www.boe.ca.gov/pdf/boe8.pdf.

California Research Credit

The State also offers a California Research Credit that is available to taxpayers engaged in qualified research. The State of California Franchise Tax Board's website[66] contains information about this income tax credit and lists four tests for determining if an activity or project constitutes qualified research to receive the credit. Because these tests require that research follow a scientific method-style process of developing and testing a hypothesis, and that eligible expenses should be connected to experimental or laboratory costs, it seems unlikely that this credit will apply to hydrogen station developer activities unless some new approaches to hydrogen production, storage, or dispensing are being studied as part of a project. If a station developer believes that some of its activities do qualify, form FTB 3523 must be completed to claim the credit.

Financing Programs

IBank Financial Resources for Hydrogen Fuel Production and Small Businesses

The California Infrastructure and Economic Development Bank (IBank) finances public infrastructure and private development through a variety of programs.

The California Lending for Energy and Environmental Needs (CLEEN) Center encourages public investment in infrastructure projects that meet State objectives to conserve water, reduce greenhouse gas emissions, and generate clean and renewable energy. Municipalities, Universities, Schools, and Hospitals (the MUSH markets), as well as 501(c)(3) nonprofit organizations with a public sponsor, are eligible to receive CLEEN Center funding. Eligible projects may include hydrogen refueling stations, alternative technologies for renewable hydrogen generation, hydrogen fuel cell energy storage, and transmission and distribution. Direct loan CLEEN Center funding is available in a range of amounts from $500,000 to $30 million, or more with Board approval.[67]

In the Small Business Loan Guarantee Program, IBank partners with financial development corporations to guarantee loans made by financial institutions, with guarantees up to 80 percent on loans no greater than $20 million, to provide incentives for lenders to make loans to

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66 State of California Franchise Tax Board. California Research Credit. https://www.ftb.ca.gov/businesses/credits/rd/.

67 IBank. *Criteria, Priorities, and Guidelines for the Selection of Projects for IBank Financing Under the California Lending for Energy and Environmental Needs Center.* August 2015. http://www.ibank.ca.gov/ibank/programs/what-is-cleen (see "Who Can Apply" section).

small businesses. Acceptable loan purposes include start-up costs, purchasing equipment, expanding facilities, new construction or renovation, and lines of credit.[68]

IBank offers industrial development bonds and tax-exempt financing up to $10 million for qualified manufacturing and processing companies for the construction or acquisition of facilities and equipment. Industrial development bonds allow private companies to borrow at low interest rates normally reserved for state and local governmental entities. IBank also offers exempt facility bonds, which include tax-exempt financing for projects that are government-owned or consist of private improvements within publicly owned facilities, such as private installation of hydrogen refueling stations and hydrogen fuel cell energy storage improvements at publicly-owned schools.[69]

Volkswagen Infrastructure Investment Commitment

On October 25, 2016, the United States District Court for the Northern District of California approved a Partial Consent Decree (Consent Decree) between ARB, the United States Environmental Protection Agency, the United States Department of Justice, and Volkswagen. The Consent Decree partially resolves Clean Air Act and California claims against Volkswagen for the use of defeat devices in their 2.0 liter diesel vehicles; it does not resolve potential 2.0L penalties, 3.0L claims, or 2.0L or 3.0L criminal liability that may be associated with this case. The text of the Consent Decree can be found at www.cand.uscourts.gov/filelibrary/2869/Order-Granting-Entry-of-Consent-Decree.pdf. There are four elements to the Consent Decree, including Appendix C, which specifies the terms and framework for Volkswagen's Zero Emission Vehicle Investment Commitment. Volkswagen will be directly expending the required funds. Infrastructure is one of the eligible investment areas, including hydrogen fueling infrastructure. Volkswagen created a website that provides additional information and allows interested parties to submit funding ideas or strategies, located at https://www.electrifyamerica.com/our-plan.

Low Carbon Fuel Standard

In 2009, and with subsequent review and re-adoption in 2015, ARB adopted the Low Carbon Fuel Standard (LCFS) to further reduce California GHG emissions and to "reduce the full fuel-cycle, carbon intensity of the transportation fuel pool used in California" (Health & Safety Code [H&S], section 38500 et seq.).[70] The regulation reduces lifecycle GHG emissions by assessing a "Carbon Intensity" (CI) score to each transportation fuel based on its lifecycle assessment.

The regulated parties are all types of fuel providers including hydrogen. Producers who do not meet the LCFS standards may purchase LCFS credits to offset emissions created by their fuels.

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68 California Infrastructure and Economic Development Bank. Small Business Finance Center. http://www.ibank.ca.gov/programs/what-is-the-sbfc.

69 California Infrastructure and Economic Development Bank. Bond Financing Program. http://www.ibank.ca.gov/ibank/programs/bonds.

70 California Air Resources Board. Low Carbon Fuel Standard. https://www.arb.ca.gov/regact/2015/lcfs2015/lcfsfinalregorder.pdf

A fuel that has a CI that is below the standards in a given compliance period generates credits. Conversely, the LCFS allows these fuel providers to generate LCFS credits that they can sell and trade in the California LCFS market.

In October 2016, ARB reported that the average trading price of one LCFS credit (equal to one metric ton of CO_2) was $89. Over the past year, the quarterly average trading price ranged from $89 to $114 per credit.[71]

Future ARFVTP Funding

AB 8 directs the Energy Commission to annually allocate up to $20 million from the ARFVTP for the development of hydrogen refueling stations until at least 100 stations operate publicly. AB 8 is in effect until January 1, 2024.

71 California Air Resources Board. Monthly LCFS Credit Transfer Activity Reports. https://www.arb.ca.gov/fuels/lcfs/credit/lrtmonthlycreditreports.htm

APPENDIX H:
California Stations

The California stations, as of December 5, 2016, are listed in Table H-1. Table H-1 shows the progress of the hydrogen refueling station network, from six open retail stations reported at the end of 2015 in contrast to the 25 open retail stations reported at the end of 2016.

Table H-1: County, Address, and Station Type
(Type Column Key – 1: delivered gaseous, 2: delivered liquid, 3: electrolysis,
4: delivered gaseous with H35 dispensed from medium pressure storage tanks,
5: SMR, 6: Pipeline)

County	Address	Type	Operational	Open Retail
Alameda	1172 45th Street Emeryville, CA 94608	1	9/16/11	N/A
	41700 Grimmer Boulevard Fremont, CA 94538	1	pending	
	391 West A Street Hayward, CA 94541	1	2/26/16	4/27/16
	1100 Seminary Avenue Oakland, CA 94621 (transit bus only)	2 and 3	12/7/14	N/A
Contra Costa	2451 Bishop Drive San Ramon, CA 94583	2	pending	
Fresno	24505 West Dorris Avenue Coalinga, CA 93210	1	10/9/15	12/11/15
Los Angeles	145 West Verdugo Avenue Burbank, CA 91510	5	11/24/10	N/A
	21865 East Copley Drive Diamond Bar, CA 91765	1	7/21/14	8/18/15
	25800 South Western Avenue Harbor City, CA 90710 (O&M only)	1	3/31/13	N/A
	550 Foothill Boulevard La Canada Flintridge, CA 91011	1	12/10/15	1/25/16
	15606 Inglewood Avenue Lawndale, CA 90260	1	pending	
	3401 Long Beach Boulevard Long Beach, CA 90807	1	10/30/15	2/22/16
	10400 Aviation Boulevard Los Angeles, CA, 90046	4	2/1/09	N/A
	7751 Beverly Boulevard Los Angeles, CA 90036	1	4/8/16	5/2/16
	5700 Hollywood Boulevard Los Angeles, CA 90028	1	4/28/16	11/10/16
	8126 Lincoln Boulevard Los Angeles, CA 90045	1	6/17/16	8/18/16
	11261 Santa Monica Boulevard Los Angeles, CA 90024	1	4/20/15	10/29/15
	5151 State University Drive Los Angeles, CA 90032 (O&M only)	1	5/7/14	N/A

County	Address	Type	Operational	Open Retail
	5957 Vineland Avenue North Hollywood, CA 91601	3	pending	
	28103 Hawthorne Boulevard Rancho Palos Verdes, CA 90275	1	pending	
	24551 Lyons Avenue Santa Clarita, CA 91321	1	pending	
	1200 Fair Oaks Avenue South Pasadena, CA 91030	1	pending	
	1819 Cloverfield Boulevard Santa Monica, CA 90404	1	12/10/15	2/1/16
	2051 West 190th Street Torrance, CA 90501	6	5/10/11	N/A
	5314 Topanga Canyon Road Woodland Hills, CA 91364	1	8/18/16	10/5/16
Marin	570 Redwood Highway Mill Valley, CA 94941	1	4/22/16	6/16/16
Nevada	12105 Donner Pass Road Truckee, CA 96161	1	4/22/16	6/17/16
Orange	3731 East La Palma Avenue Anaheim, CA 92806	4	8/31/16	11/29/16
	2050 Harbor Boulevard Costa Mesa, CA 92627	1	12/2/15	1/21/16
	19172 Jamboree Road Irvine, CA 92612	1	9/10/15	11/12/15
	20731 Lake Forest Drive Lake Forest, CA 92630	1	2/20/16	3/18/16
	1914 East Chapman Avenue Orange, CA 92867	3	pending	
	1600 Jamboree Road Newport Beach, CA 92660	5, to be converted to 2	2/24/12	N/A
	26572 Junipero Serra Road San Juan Capistrano, CA 92675	2	9/21/15	12/23/15
Riverside	8095 Lincoln Avenue Riverside, CA 92504	3	10/31/15	
San Bernardino	12600 East End Avenue Chino, CA 91710	3	pending	
	1850 Holt Boulevard Ontario, CA 91761	3	pending	
San Diego	310 Encinitas Boulevard Encinitas, CA 92024	1	pending	
	3060 Carmel Valley Road San Diego, CA 92130	1	9/30/16	12/2/16
San Mateo	248 South Airport Boulevard South San Francisco, CA 94080	1	10/30/15	2/12/16
	17287 Skyline Boulevard Woodside, CA 94062	1 and 3		
Santa Barbara	150 South La Cumbre Road Santa Barbara, CA 93105	1	2/25/16	4/9/16
Santa Clara	2855 Winchester Boulevard Campbell, CA 95008	1	2/25/16	6/9/16

County	Address	Type	Operational	Open Retail
	2300 Homestead Road Los Altos, CA 94024	2	pending	
	830 Leong Drive Mountain View, CA 94043	2	pending	
	3601 El Camino Real Palo Alto, CA 94036	4	pending	
	2101 North First Street San Jose, CA 95131	1	10/30/15	1/15/16
	12600 Saratoga Avenue Saratoga, CA 95070	1	2/22/16	3/14/16
Sonoma	5060 Redwood Drive Rohnert Park, CA 94928	3	pending	
Ventura	3102 Thousand Oaks Boulevard Thousand Oaks, CA 91362	3	pending	
Yolo	1515 South River Road West Sacramento, CA 95691	2	9/17/14	7/7/15

Source: California Energy Commission staff and ARB

Figure H-1: Riverside Station Dispenser

Source: ITM Power

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